COMPONENT RELIABILITY DATA
FOR USE IN
PROBABILISTIC SAFETY ASSESSMENT
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FOREWORD

Generic component reliability data is indispensable in any probabilistic safety analysis. It is not realistic to assume that all possible component failures and failure modes modeled in a PSA would be available from the operating experience of a specific plant in a statistically meaningful way.

The degree that generic data is used in PSAs varies from case to case. Some studies are totally based on generic data while others use generic data as prior information to be specialized by plant specific data. Most studies, however, finally use a combination where data for certain components come from generic data sources and others from Bayesian updating.

The IAEA effort to compile a generic component reliability data base aimed at facilitating the use of data available in the literature and at highlighting pitfalls which deserve special consideration. It was also intended to complement the fault tree and event tree package (PSAPACK) and to facilitate its use.

Moreover, it should be noted, that the IAEA has recently initiated a Coordinated Research Program in Reliability Data Collection, Retrieval and Analysis. In this framework the issues identified as most affecting the quality of existing data bases would be addressed.

This report presents the results of a compilation made from the specialized literature and includes reliability data for components usually considered in PSA.

This report was prepared under the framework of IAEA's Programme on Probabilistic Safety Assessment by Mr. Bojan Tomic, Division Of Nuclear Safety - Reliability and Risk Assessment (NENS-RRA). Mr Luis Lederman (NENS-RRA) was the project officer.
EDITORIAL NOTE

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EXECUTIVE SUMMARY

In response to the needs of Member States conducting or planning to initiate probabilistic safety assessments (PSAs) the IAEA carried out a compilation of component reliability data from the publicly available literature.

The work was undertaken under framework of the IAEA's PSA Programme with an effort which amounted to 7 man months.

The IAEA Data Base Version 1.0 consist of about 1000 records compiled from 21 different data sources (listed in Appendix 1) and include all data for nuclear power plant components usually modelled in PSAs.

No attempt was made to interpret or adapt the information contained in the original sources. Therefore the records of the IAEA Data Base are established directly from the information from the sources surveyed. A peer review was conducted at the end of the compilation and all records have been verified. The possibility of errors is, however, not to be excluded and the prompt notification of any errors encountered by the users to the IAEA is highly appreciated.

Two of the data sources namely, Heavy Water Reactor and Old PWR have been compiled by the IAEA in the framework of various activities including workshops and technical assistance missions to Member States. Therefore their accuracy cannot be verified. They are included in the Data Base only for illustrative purposes.

The Data Base is compiled on an IBM compatible personal computer using dBASE III software and it is available for distribution in form of diskettes which can be obtained upon request from the IAEA Division of Nuclear Safety. On diskettes it can be distributed in dBASE III format (in this case the dBASE III software is needed for use of the Data Base) or in the plain textual format (any full screen editor can be used).

This report describes in detail the Data Base format, including the record form and associated coding system. It also described each data source surveyed and briefly qualifies special features of each.

Problem areas connected with data bases found in literature are also highlighted in the report.

Appendix 2 to the report provides detail description and definition of major generic failure modes considered during compilation of the Data Base.

Two appendices provide listing of the component groups and types together with associated codes. These appendices help the user in selecting the most appropriate components according to codes.

Finally, all Data Base records sorted in alphabetic order of components are listed in last Appendix.
1. INTRODUCTION

Reliability data are an essential part of a probabilistic safety assessment. The quality of data can determine the quality of the study as a whole.

Component failure data originating from the plant being analyzed would be the most appropriate. However, reliance on experience at the plant is rarely possible, mainly owing to the rather limited operating experience and usually small number of recorded failures. The use of generic component reliability data is therefore unavoidable.

A relatively large amount of component reliability data is available in the open literature today. Some of these data were used in PSA studies; others were collected from sources, such as nuclear or conventional operating experience, and industrial and military records.

All these data are scattered throughout many different publications. Some are not easily obtainable, and others may not be readily available to the user. To facilitate the use of generic data from the existing literature by PSA analysts IAEA has compiled the data available from a number of different sources.

The other reason for compilation is to have the data base as part of the PSAPACK code package (developed at the IAEA). PSAPACK is the package used to perform of Level 1 of the PSA, including event tree and fault tree analysis.
2. USE OF THE DATA BASE

The IAEA's Component Reliability Data Base can be used in two ways: alone as data source, and as a part of the PSAPACK.

2.1. Use as a stand-alone

The IAEA Data Base was compiled using dBASE III commercial software; this software package is therefore needed to use the Data Base alone.

Using the dBASE software one can browse through records, list them, and retrieve information stored to the screen or print it in different ways. With dBASE III commands it is possible to select individual records or groups of records with given common characteristics (for example source, component type etc.).

The purpose of the Data Base for stand-alone use is to have readily available several data sources for each single component. The data base can also be used for assessing total ranges of data (extremes).

One of the peculiarities of the Data Base is that failure rates (as well as upper and lower bounds) are stored in the character format (instead of numerical), so direct calculation is not possible. The reason for it is that dBASE III software does not allow numbers to be presented in exponential format.

2.2. Use with the PSAPACK computer code package

For use with PSAPACK code package the IAEA Data Base is stored in textual format, what means that each record is presented as a 900 character line. PSAPACK includes a small interface code which enables viewing of each single record in the Data Base. After assessing the most appropriate record for particular analysis, it is retrieved and stored in the small data base. At this point the user can append or change any data point. Failure rates (or probabilities) stored in the newly formed small data base are then automatically used in the analysis. More detail about use with PSAPACK can be found in its users manual.
3. DATA BASE FORMAT

3.1. Record form

With many different sources providing different types of information, it was necessary to define a unique record form which would enable inclusion of information in a systematic and consistent manner. The second objective was to have a system which can enable easy information overview and retrieval.

The record form was defined as having 21 lines, presenting 10 categories of information (table 1).

Table 1: Record categories

| 1. code             | 1 line |
| 2. component type   | 4 lines |
| 3. operating mode   | 1 line |
| 4. operating environment | 1 line |
| 5. failure mode     | 2 lines |
| 6. failure rate     | 5 lines |
| 7. repair time      | 1 line |
| 8. source           | 2 lines |
| 9. component boundary | 1 line |
| 10. comments        | 3 lines |

1. Every record has a code which is a unique combination of 5 alphanumeric characters. A detail description of the coding system is presented later.

2. Component type is described in 4 lines, namely: type, subtype, detail type 1 and 2. Type characterizes a basic component type (e.g. "pump", "valve"). Subtype characterizes more specifically the component category (e.g. motor driven pump, solenoid operated valve, pressure sensor, AC motor). Some of the components do not have information at this level (e.g. battery charger). Detail type 1 contains information about the system where the component belongs or other detail characteristics as voltage, or pipe diameter etc. Valve types (e.g. gate, butterfly, etc.) are also included in this line. "General" means that further characterization is not possible. Detail type 2 is the last entry of the component description. Usually, very detailed information about component type is not available. When information is available on component size or about the system to which the component belongs this is found in this line.

3. Operating mode is the next category. Operating mode is a particularly important characteristic for pumps (standby, alternating or running). For other components this information is of less importance. Precise information of that type are seldom found in data sources. When the component operating mode is obvious, (e.g. safety injection pump is a standby pump) this information is included. In other cases "all" operating modes was the default value chosen.

4. Operating environment is the next entry which, similar to the previous one, is seldom found in data sources. It is obvious that volatile environment should influence the component failure rate, but very few sources address that fact. For example IEEE 500 provides multiplication
factors for most of components listed and for environments like high
radiation, temperature or humidity.

WASH 1400 provides different failure rates for pumps and motors in
extreme, post accident environment. Failure rates are, particularly in the
cases where the operating experience is the basis for determining the
failure rate, usually based on normal operating environment.

When addressing component operating environment, some of the sources
define "normal NPP environment" as the usual one.

A default value "normal" was chosen in all cases where no other
environmental condition was indicated.

5. The failure mode category is presented in two entries, one
describing "generic" failure mode and other presenting failure mode found
in the original source. Details about the failure modes are discussed in
Appendix # 2. Briefly, a generic failure mode was assigned because the
coding system was not able to cope with the number and differences in
failure modes found in the sources. The original failure mode was, however
left in the record for users' clarification.

6. The failure rate is presented in 5 entries. The first entry is
the failure rate description, containing information about the failure
rate (mean or median), upper and lower bounds (percentiles of the
distribution, low and high or maximal and minimal values), and defining
the failure rate as per hour (operational or standby) or per demand. The
failure rate entry provides the actual numerical value for the mean,
median, or best estimate value. Upper and lower bound entries provides
respective numerical values. If the error factor is available it is given
in the fifth line. Upper and lower bounds and error factors are not always
available. When not available, n/a (meaning not available) is written.

7. Repair time is the next category. It indicates the average repair
time associated with a component failure. It is also rarely found in
generic sources. Some sources provide duration based on recorded repair
times, others consider repair time as a mean value of several maintenance
durations on a particular component. For the real case generic information
of this kind is not of much use.

8. Information regarding source of data is presented in two lines,
one indicating the exact source (name of publication, page #., table #.)
and second information about the ultimate source of data (e.g. expert
opinion, operating experience).

9. Component boundary is a main problem area when using generic data
sources. Very few sources provide adequate information about component
boundary. The best information is found in the Swedish Reliability Data
Book, where a sketch showing exact component boundaries is provided for
each component. Whenever exact boundary information is not available,
"detail not available" is written.

10. Comment entries are the last category of a record. Usually all
the information found in the sources and considered relevant are written
here. If the data source is a generic source updated with specific plant
operating experience, the prior source and/or mean and operating
experience (total population covered, number of demands or operational
time, number of failures) used in updating is recorded. Additional failure
rates relevant to the component (e.g. failure rate with or without command faults) are also included in the comment lines.

Practically all information which could be used to clarify failure rates, failure modes or component description are written. The comment category is an integral part of each record and it is very important to consider information included there when choosing any record for further calculation or comparison.

The complete record form is shown in Table 2 below.

<table>
<thead>
<tr>
<th>Table 2: Complete record form</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MODE</strong></td>
</tr>
<tr>
<td><strong>TYPE</strong></td>
</tr>
<tr>
<td><strong>SUBTYPE</strong></td>
</tr>
<tr>
<td><strong>DETAIL</strong></td>
</tr>
<tr>
<td><strong>DETAIL1</strong></td>
</tr>
<tr>
<td><strong>OPMODE</strong></td>
</tr>
<tr>
<td><strong>OPENVIRO</strong></td>
</tr>
<tr>
<td><strong>GENFAILMOD</strong></td>
</tr>
<tr>
<td><strong>FAILMODE</strong></td>
</tr>
<tr>
<td><strong>FRATEDESCP</strong></td>
</tr>
<tr>
<td><strong>FAILRATE</strong></td>
</tr>
<tr>
<td><strong>UPBOUND</strong></td>
</tr>
<tr>
<td><strong>LOWBOUND</strong></td>
</tr>
<tr>
<td><strong>ERRORPCTOR</strong></td>
</tr>
<tr>
<td><strong>REPAIRIN</strong></td>
</tr>
<tr>
<td><strong>SOURCE</strong></td>
</tr>
<tr>
<td><strong>ULISOURCE</strong></td>
</tr>
<tr>
<td><strong>COMMENTS</strong></td>
</tr>
<tr>
<td><strong>COMMENTS1</strong></td>
</tr>
<tr>
<td><strong>COMMENTS2</strong></td>
</tr>
</tbody>
</table>

3.2. Coding system

Coding system is the area where the PSAPACK code mostly influenced the IAEA Data Base structure. In accordance to the PSAPACK requirements, each record code could have up to 4 alphanumeric characters. The fifth character in the code is the character describing the source but the PSAPACK does not use this information.

Some of the fault tree analysis codes included in the PSAPACK limit identification of basic event to eight alphanumeric characters. It was felt that at least 4 characters are needed for further identification of components (including its physical position for eventual common cause or dependency analysis). Therefore only 4 characters were used for basic component identification and failure mode description.
Three positions were used to code the component type. There is a hierarchical structure associated with components' coding.

The first character of the code define the category to which the component belongs to. There are 22 distinct component categories.

The next hierarchical level is the component group level. There are between 1 and 10 groups in each category, totaling more than 100 component groups. Each group has a unique two alphanumeric characters code. List of component groups is provided in Appendix 3.

The lowest hierarchical level is the component type. IAEA Data Base contains more than 420 different component types. Each component type has a unique three alphanumeric character code (list of component types and associated codes is given in Appendix 5).

Some of the component groups do not have subdivisions, in these cases the component type is defined on the second hierarchical level. The word "general" is sometimes used to describe that the failure rate in that particular record is for general use irrespectively of the detailed component type. In these cases the third character of the code is "A" meaning that no information about detail type is available for the particular component.

As there is no space in the coding system for operating mode or environment, sometimes the same component is coded differently because of operating conditions (e.g. motor driven pump (general) is coded 'EMB' when in alternating operating mode, and 'FMR' when in running mode).

The next position in the code describes the component failure mode. Originally, there were more than 100 different failure modes coming from various sources. To code all of them two positions were required. As the generic failure modes were designed, one character was sufficient to describe the component failure mode.

Appendix 2 provides an inclusive list of generic failure modes and associated codes.

The last position of the code is describing the source of data. The list of source codes is provided in Appendix 1.

3.3. Generic failure mode definitions and usage

More than 100 failure modes were identified during the data base compilation. Such a high number of failure modes caused problems not only in coding but also makes any failure rate comparison difficult and sometimes impossible. On the other side, the majority of failure modes differ only in wording (e.g. 'fail to run'; 'failure to run'; 'failure during operation' describing running failure of pump). Therefore, a set of generic failure modes was defined (covering practically all component failure modes accounted for in PSA's) and each of the original failure modes was listed under one of the generic categories.

Details about generic failure mode definition process and rather definition of each of the major failure modes are found in Appendix 2.
4. COMPONENTS OF THE DATA BASE

The IAEA Data Base contains about 1000 records. More than 430 different components are addressed, having on average 2.2 failure modes. There are two main reasons for the existence of such a high number of component types (high compared to about 50 components used in average PSA). The first is the relatively large number of sources, so sometimes the same component is defined in different way (more or less detail). A second reason is that the primary objective of some of the data sources was not PSA. Therefore components in these sources are defined with greater detail (sizes of valves etc.) causing distinction between components.

Components found in the IAEA data base can be divided in four major categories:

- mechanical components
- electrical components
- instrumentation and control (I & C) equipment
- emergency power sources

Mechanical components category include the following component categories (unique first character of the code for respective category is given in brackets):

- piping (F)
- heat exchangers (H)
- control rods and drive mechanisms (O)
- pumps (P)
- HVAC and air handling equipment (Q)
- valves (V)
- strainers/filters (Y)
- other mechanical equipment (J)

Electrical equipment category include following:

- transformers (T)
- relays (R)
- motors (M)
- conductors (C)
- batteries and chargers (B)
- circuit breakers (K)
- other electrical equipment (E)

Instrumentation and control equipment category consist of following:

- sensors (A)
- instrumentation (channel) (I)
- transmitters (L)
- signal conditioning systems (N)
- switches (S)
- other I & C equipment (U)

Emergency power sources category include diesel generators and gas turbine driven generators. (D)
4.1. Component groups

Each of the above listed categories contain several component groups (up to 10). Component groups are defined as the aggregation of the component having similarity on the second level. The examples of component groups are 'motor operated valves', 'diesel driven pumps', 'flow sensor' and 'main power transformer'. Group is also a second hierarchical level in the component coding system. There are more than 100 component groups in the IAEA data base.

4.2. Component types

Component detailed type is the lowest hierarchical level. Sometimes the component group is equal to the component detailed type. In other cases components in the group are different in sizes, system they belong to, detailed design characteristics etc. The population of each group as well as the level of detail vary substantially.

4.3. Selection of applicable data

The selection of data for a particular study greatly depends on the type of study, status of system (or plant) analyzed (planned, in design process, operational) and level of resolution needed. Data selected for the study should as close as possible match analysis requirements and major characteristics of data sources (including characteristics pertinent to ultimate source).

When selecting data the user has to consult Chapter 6 of this manual where the basic information about each of the sources included are presented. The user has to be aware that the data from a single source could be based on several different ultimate data sources (e.g. operating experience and expert opinion). Therefore in addition to the description of the source found in the manual, the ultimate data source entry in each record provides additional guidance. Sometimes information found in comment lines can also help in data selection.

In general it is recommended that sources having characteristics similar to the plant under consideration should be selected.

Another important point in data selection is the type of the analysis intended (point estimate or uncertainty analysis). Inclusion of uncertainties limit available data to sources which have either confidence limits or upper and lower bounds. Out of 1000 records in the Data Base, about 700 have upper bound, and less than 650 include lower bound. Error factors are found in about 300 records.

If the analysis require generic repair time, it further limit available data. Repair time is given in about 320 records. Problem with the repair time is that it is unequally distributed (e.g. few sources include repair time).
To facilitate the selection of a particular component the user should consult Appendices 3 and 4, where component groups and types are listed in alphabetical order together with respective two or three character codes. After selecting the component type which is applicable for the case studied, the user can locate a particular record by its code.

Most of the components listed have more than one failure mode. It is expected that component types and failure mode needed in PSA are contained in the IAEA Data Base. It is suggested that prior to final fault tree construction, analyst familiarize himself with the information available.
5. DATA SOURCES FOR THE DATA BASE

5.1. General characteristics

One of the objectives of the data base compilation was to have data from many different sources. Twenty one sources were chosen for inclusion. The amount of information contained in the various sources, however, differ substantially. Some of the sources provide up to 180 different records, while one source was cited in only two of the records.

All the sources can be put into three basic categories. Each category show some unique characteristics. However, some of the sources belong to more than one category, since data contained were derived from different ultimate sources.

The three categories are now described, followed by a description of the characteristics of each single data source.

5.1.1. Plant specific data

Two basic subgroups exist inside this category. The first is plant specific data drawn directly from sources available at the plant (logbooks, maintenance records, work orders, etc.), and the second one is when generic data is updated with plant specific information.

The first subgroup is normally considered to be the best source of data for the plant analyzed, but this is not necessarily the case when one uses these data at another plant. Generally, this is a source that is rarely found in the literature. The only source in the IAEA Data Base fully in this category is NUREG 4550 (Vol.3, Surry NPP) and this provides only ten records.

The second subgroup is of generic data updated with single plant operating experience. This procedure is usually applied either when limited plant specific data are available, or when available data could tend to overestimate or underestimate component reliability. In fact, in most of the recently completed PSA studies (which are not using generic data bases) component reliability data are derived in this manner. The IAEA Data Base includes several sources of this kind (e.g. Oconee NPP PRA, Zion NPP PRA and a source identified as "Old W PWR").

5.1.2. Data extracted from reporting systems

A widely known NPP event reporting system is the Licensee Event Report System used in the USA. Safety significant events occurring at NPPs have to be reported, and it is therefore possible to identify component failures related to these events. Identification of component failures is not always straightforward, and other means of identifying the components involved have to be used.

The IAEA Data Base includes four sources of this kind. These are NUREG/CR-1205, NUREG/CR-1363, NUREG/CR-1331 and NUREG/CR-1740. All these sources provide failure rates assessed from licensee event reports.
Similar in a way to the LER based rates are the failure rates published in the Swedish "Reliability Data Book", which provides the reliability parameters derived from Swedish LERs, the ATV system (The Swedish Thermal Power Reliability Data System) and information provided by the plant staff.

The advantage of reliability parameters derived in this manner are that the actual component population covered is very large which guarantees more reliable statistics. However, LER systems are event oriented and not component oriented, so actual component failure could be misinterpreted or overlooked. In addition, some component failures are not reported in the system because the failures either caused no safety significant event or were not required to be reported. Furthermore, a small percentage of events is not reported because of the plant personnel's general attitude to the reporting system. All these factors may lead to possible overestimates of component reliability.

Another problem area is the operating time and the number of demands on the component. Operating time is usually estimated on the basis of reactor operating time, and the number of demands is estimated as an average also based on the operating time. Assessment of these parameters (instead of recording them) opens a possibility of substantial errors. This can drive calculated failure rates in either direction.

Compilations of this kind tend to underestimate differences in component design, operational practices and environment, which is sometimes very important information and can greatly influence component reliability.

To conclude, reliability parameters found in this type of source should be used with care in PSA studies.

5.1.3. Data based on expert opinion, nuclear and non-nuclear experience

Categories in this group include single expert opinion, aggregate expert opinion, aggregation of several non-nuclear sources, aggregation of expert opinion and other sources and aggregation of operating experience of several NPPs. Even a single data source usually includes several of these categories. Aggregation of data (if properly performed) provides more reliable data than single expert opinion or a single source.

The most widely known representative of this category is the IEEE Standard 500. Its 1977 version mostly includes expert opinion, while the 1984 version also includes nuclear and non-nuclear experience. Other examples of data sources which are included in the IAEA Data Base are: NUREG/CR-2728 Interim Reliability Evaluation Program Procedure Guide, (which adopted the data base from EGG-EA-5887), NUREG/CR-2815 Probabilistic Safety Analysis procedure guide (data from expert opinion combined with the IREP data base) Sizewell B assessment (operating experience, including nuclear and other industrial sources).

The WASH-1400, Reactor Safety Study, (a combination of expert opinion and non-nuclear and nuclear sources) also belongs to this category and it is important to mention that it is still a widely used source. Two sources
The quality and reliability of data in this category can vary substantially, depending on the ultimate source, the method of collecting raw data and the methods used to derive failure rates.

Although expert opinion is sometimes considered to be a low quality data source, it is important to mention that it is proved several times to be in very good agreement with data from actual operating experience.

5.2. Characteristics of single data sources

In addition to the general characteristics of the data sources described in the previous paragraph, each data source included in the IAEA Data Base show some unique characteristics. To facilitate proper use of the data base and to avoid misinterpretation due to limited knowledge of the ultimate data source, some characteristics of each data source are presented. Sources which seem to be more important, or simply widely used or cited more often, are described in greater detail.

The data sources used for the compilation of the IAEA's Generic Component Reliability Data Base are listed in Appendix 1 (in alphabetical order).

5.2.1. WASH 1400 Reactor Safety Study

5.2.1.1. General

WASH 1400 was the first and is the most widely known probabilistic safety study performed. Considerable effort was made in the study to develop the data needed. Although the study is rather old, it is even today sometimes still used as a source of data.

5.2.1.2. Data sources

The data used in the study were derived from different sources, including reports, handbooks, industrial operating experience and NPP experience. Ultimate data sources included the US Department of Defense (Navy, Air Force), NASA data, general industrial operating experience and nuclear power plant experience.

The log normal distribution was used to describe data variability (the log normal distribution is also used in most of the data sources). Log normal distribution is a two parameter distribution and two end points in a defined range determine a unique distribution. In the study the 90% range was selected, the lower end being 5% bound
and the upper 95% bound. This definition of range implies that there is a 90% probability that the data value would be within this range.

The ultimate data sources considered represent a variety of applications and conditions, with some sources apparently being more applicable than others. However, data sources are in general within one or two orders of magnitude.

Since order of magnitude accuracy was required, endpoints were determined to the nearest half integer on the exponent scale (i.e. $10^{-1}$ or $10^{-1.5}$). The half integer on the scale corresponds to the assignment of 3 or 1 for the significant figure (i.e. $10^{-1}$ or $3\times10^{-2}$).

The actual range was assessed after a number of iterations, involving a large number of components. Data points selected came from various sources (including nuclear experience), and the range was chosen to cover approximately 90% of the points. The actual determination of the range required data plotting with a decision made on the weight of each data point. The assessment decisions were based on the experience of individuals involved in reliability studies and NPP operation. Because of the order of magnitude accuracy, components were generally classified only according to their generic types. When available, actual nuclear plant experience was used as the principal basis for determining and checking the assessed range.

Sources, other than commercial nuclear experience, which provide the data points used in range assessment can be divided into two categories: general sources and special sources. Some of sources which provide most of the data points are:

1. System Reliability Service, UKAEA (all service publications)
2. Reliability Engineering Data Services Failure Rates, AVOO Corp. 1962 (Contains failure rates assessment for primary military hardware)

Commercial reactor operating experience was examined to serve as important data for an assessment of data ranges. Sources for failure examinations included 1971–73 incident files and reports of operating occurrences, Nuclear Safety Information Center files, environmental reports, individual technical reports and other pertinent sources. In particular, a one year period (January –December 1972) was used to evaluate the summarized and averaged nuclear data statistics.
Out of a total number of 700 failures reported that year, the number of failures and abnormalities that occurred at plants operational for the full year (eight PWRs and nine BWRs) and that were safety related was 303. These failures were categorized by generic component into classes. A statistical evaluation was performed in order to estimate failure rates and demand probabilities.

The pertinent environment for all components, except pumps, is that of standard nuclear power plant operational conditions. The assessed ranges should cover variations occurring in that environment. Failure of a pump to run was also assessed for extreme temperature and pressure conditions characteristic of a severe accident.

The advantage of the data in WASH-1400 is that a variety of different ultimate sources were considered in the assessment process. Nuclear operating experience was also considered (although in limited scope) and the assessed range was checked for applicability.

The disadvantage of the process lies in the obvious difference in ultimate data sources. The difference comes from the variety of applications, maintenance practices, design differences, etc. Another problem is the different methods of collecting and reporting data, component definitions and environmental and related factors. However, by assessing ranges instead of point values, these differences can be made less important.

The data from WASH-1400 were widely used afterwards, and many reports on nuclear components reliability data provide some kind of comparison with WASH-1400 data on components analyzed.

During the review process of WASH-1400 it was concluded that the ranges (confidence levels) of several components were too narrow; in other words, confidence levels tended towards overconfidence. Some of the later PSA studies (Zion PSS for example) used WASH-1400 confidence limits, but instead of 5% and 95% bounds, they used the limits as the 20% and 80% bounds, implying that with a 40% probability the true value lies outside these bounds.

5.2.1.3. Data available in the IAEA Data Base

In the IAEA Data Base, 'failrate' is the median value from WASH-1400 Appendix 3, Tables 4-1 and 4-2, 'upbound' is the 95% value and 'lowbound' is the 5% value, thus representing 90% confidence levels. The error factor for assumed lognormal distribution found in the records is the upper limit of the range divided by the median, and since the median is a geometric midpoint, it is also equal to the median divided by the lower limit.

5.2.1.4. Source independence

WASH-1400 is the source widely used as a prior in data updating or for the comparison of failure rates derived from other ultimate data sources. Therefore, in terms of independence, WASH-1400 data have been repeated many times and also influenced most of the data bases compiled since. All
the data sources in the IAEA Data Base which do not rely fully on operational experience are more or less dependent on WASH-1400 data.

5.2.2. Swedish Reliability Data Book

5.2.2.1. General

The Swedish Reliability Data Book which provided the data for the IAEA Data Base is the 1985 updated version. It was compiled by ASEA-ATOM for the Nuclear Safety Board of Swedish Utilities and Swedish Nuclear Power Inspectorate. The main aim of the compilation was to provide (or improve) failure data for reliability calculations as a part of the safety analysis for Swedish NPPs.

5.2.2.2. Data sources

The sources of information were the following:

- Failure reports in the ATV system (the Swedish Thermal Power Reliability Data System)
- Licensee Event Reports to the Swedish Nuclear Power Inspectorate
- Information provided by the operation and maintenance staff of each plant.

In order to obtain well defined basic data, reports covering startup periods and periods when reporting was found not to be satisfactory were excluded. Also, the annual refueling outage and other extended shutdowns were not included in component statistics.

Altogether about 35 reactor years of BWR operating experience were analyzed. The following NPP's were covered in the study: Barsebäck 1 and 2; Forsmark 1 and 2; Oskarshamn 1 and 2; Ringhals 1. The only PWR plant covered in the study is Ringhals 2, with about 4.5 years of operating experience (ATV reports) analyzed in the Ringhals 2 Safety Study. Another 1.5 reactor years of experience was analyzed using the same sources as for BWR plants.

The total number of ATV reports analyzed was 3575. Of these 590 represent critical failures. In addition, 60 Licensee Event Reports were analyzed.

The Data Book presents reliability parameters for pumps, valves, control rods and drives, electrical components and instrumentation. Components included are mainly those belonging to safety related systems.

The number of demands used for calculating probabilities of failure per demand has been obtained from the test interval defined in Technical Specification and from other demands connected with plant disturbances (e.g. scram).
The operating time needed for failure rate calculations was estimated from the operation profiles of the plant together with readings of operating time (e.g. pumps).

The repair time which appears in the Data Base is calculated as the arithmetic mean of the repair times given in the failure reports.

Two types of failure probabilities were determined:

- Failure rate (lambda), stating the probability of a component failing per unit time (applicable for components in continuous [running] and intermittent [alternating] operation)

- Failure per demand (q) stating the probability that a component does not work when demanded.

Basic assumptions applicable to statistical models for estimating parameters were the following:

- Each individual component is assumed to have a constant failure rate within the interval studied. This leads to a Poisson distribution for time related failures and Binomial distribution for demand related failures.

- Failure rate and probability vary for the analyzed population (for whatever reason). The failure characteristic in question is therefore looked upon as a stochastic variable having suitable distribution.

- The observed failure data for similar components were assumed to be stochastically independent.

The variation of parameters within the observed population of components is described in a double parametric distribution. A gamma distribution was chosen for failure rates and Beta distribution for the variation of failure probabilities.

5.2.2.3. Data available in the IAEA Data Base

Two sets of data are available in IAEA Data Base. One is composite value of all BWR plants, and other is Ringhals 2 PWR. In the IAEA Data Base 'failrate' is the mean value, while 'upbound' represents 95% of the distribution. Since the 5th percentile of most of the distributions is very small, it is not presented in the original tables. It is therefore suggested that the interval from the origin to the 95th percentile should be regarded as a measure of the uncertainty around the mean value.

In the comment lines of most of the records in the IAEA Data Base which originated from the Swedish Data Book, values for alpha and beta (abbreviated as 'a' and 'b' respectively), the parameters uniquely describing the distributions, are found. These parameters were obtained using different methods, namely:
The Maximum Likelihood Method;  
The Weighted Marginal Moment Method;  
and the Weighted aPriori Moment Method.

These parameters could be used for a Bayesian estimate of the failure rate or the probability for a specific component. The procedure is relatively simple thanks to the choice of gamma and beta as prior distributions. Posterior distributions are then of the same kind and mean values of these distributions are easy to calculate. The detailed procedure can be found in paragraph 5.2. of the Swedish Data Book.

5.2.2.4. Special features

One of the great advantages of the Swedish Data Book is its component boundary definitions. For most of the components found in the Data Book, sketches indicate the exact interface points.

The components in the Swedish Data Book (mostly pumps and valves) are also allocated to very specific categories in accordance with their main design characteristics or sizes.

Generally this source is considered to be very good, in the sense of the total number studied (for most of the components), the number of recorded failures and the definitions of components and failure mode.

As with the other sources which draw the raw data from plant experience collected in either event or failure reporting systems, the exact number of demands or operating time (for standby or alternating components) is estimated rather than recorded. The error is usually on the conservative side.

5.2.2.5. Source independence

As regards independence, the Swedish Reliability Data Book is completely independent of all the other sources included in the IAEA Data Base.

5.2.3. NUREG 2815, Probabilistic Safety Analysis Procedure Guide

5.2.3.1. General

Appendix C of NUREG 2815 provides a generic data base which includes about 40 component types (commonly found in PSA studies), with appropriate failure modes. The data base was generated from the estimates produced at a two days Reliability Data Workshop held at NRC in Washington in April 1982.
This data base is meant for general use, in cases where plant specific data are lacking. The level of detail is therefore not high. Component types represented in NUREG 2815 are basically generic categories broad enough to accommodate general use. The same applies to the failure modes assigned.

5.2.3.2. Data sources

Participants at the workshop were experts in data analysis and risk assessment and represented the NRC, utilities, national laboratories and nuclear consulting firms. For each component failure mode a nominal failure rate value and an error factor representing an approximate 90% upper bound and a 10% lower bound value were generated. Failure rates and error factors generated in this way were combined with failure rates and error factors given in the IREP users' guide (NUREG/CR-2728). The results of that combination were the failure rates given in NUREG 2815 and reproduced in the IAEA Data Base.

The procedure for the combination of expert generated estimates and IREP values was as follows:

(1) For the given component failure mode, the maximum nominal value and the maximum error factor were selected from the two sources.

(2) The selected nominal value was then multiplied and divided by the appropriate error factor to obtain upper the 90% and lower the 10% bounds.

(3) A truncated log uniform distribution (i.e. flat on the log scale) was fitted to the two bounds and a mean value was then calculated.

For most components, expert estimates and IREP values agreed. Where there was a disagreement, either in the nominal value of the error factor, it was by a factor of three or less. In these cases generic values were conservatively biased and had the largest assigned error factors.

5.2.3.3. Special features

For some of the components there is a description of what is included in the component boundary considered. However, precise interface points and other information for most of the components are not available. This is a general characteristic of all the sources not directly linked to operating experience. For future use of this data source, the component boundary shall be considered as if the component were an 'off-the-shelf' item.

The same thing applies to the operating environment. It is recommendable to consider a normal nuclear power plant environment.

It is important to mention that all the failure rates in NUREG 2815 are defined as per hour values. For the standby components starting failures are defined per hour standby, while for operating components (as well as for failures of standby components to run) the operating time is used as a basis.
This source does not give a generic repair time in the sense of a mean duration. Instead, it is suggested that the maximum allowed unscheduled downtime given in the plant technical specification should be used.

Although it is not clearly stated, expert estimates seem to be consensus estimates. Consensus is considered to be the highest ranking of all group expert estimates.

5.2.3.4. Data available in the IAEA Data Base

In the IAEA Data Base 'failrate' is the mean value of the truncated log uniform distribution, while 'upbound' is the maximum and 'lowbound' the minimum bound of the truncated log uniform.

5.2.3.5. Source independence

This source closely linked with IREP data base. As its major ultimate source is expert opinion, it can be expected that the experts estimates were relatively highly influenced by other data bases which were published prior to this. Also there is a high probability that the same experts were contributing to the other data bases, as well (for example IEEE 500 1984). Therefore NUREG 2815 data have to be considered relatively highly dependent on other US sources published at that time or before.

5.2.4. NUREG 2728 IREP (Interim Reliability Evaluation Program Procedure Guide)

5.2.4.1. General

The IREP Procedure Guide provides a generic data base which was used for screening calculations for preliminary point estimates. As the level of resolution given by the use of plant specific data is greater than that with generic data, dominant accident sequences were evaluated using plant specific data whenever possible.

5.2.4.2. Data sources

The IREP generic data base has been adapted from information contained in the EGG-EA-5887 (A.J.Oswald et al.:Generic Data Base and Models chapter of the NREP Guide, EG&G Idaho, June, 1982). Nominal values from this report were taken as medians. Associated means were calculated from the medians and error factors (representing 10% and 90% bounds), assuming a log normal distribution.

The IREP generic data base contains failure rates and demand probabilities for classes of equipment commonly found in NPP's (about 40). Four types of values are found in the data base:
Component standby failure rates, which are the reciprocals of the mean time to failure of components that are normally in standby;

Component operating failure rates, which are the reciprocals of the mean time to failure of components that are normally operating;

Demand failure probabilities for selected standby component types such as valves and pumps.

Error factors for each failure rate and demand failure probabilities representing upper and lower bounds on the value of reliability parameters. These bounds represent a range of values for each parameter that the parameter can reasonably be expected to assume.

5.2.4.3. Data available in the IAEA Data Base

The IREP generic data base contains failure rates and demand probabilities for classes of equipment commonly found in NPPs (about 40). The full set of data found in this source is reproduced in the IAEA Data Base.

The IAEA Data Base contains the mean value of the lognormal distribution as 'failrate' and an error factor.

5.2.4.4. Special features

The failure rates are in units of failures per hour. The demand probabilities represent failures per demand of the component. The median and error factor define a log normal distribution that describes the uncertainty in the reliability parameter for the failure mode, if the error factor is interpreted as representing a 90th percentile region of the parameter.

Demand probabilities in the IREP data base require further explanation. Although they are listed as demand probabilities, in reality they were originally generated by multiplying failure rates by one half of the assumed test period (one month). The demand probabilities should therefore not be taken as true demand probabilities, which depend only on the number of cycles between standby and operation. For components whose test period is not substantially different from one month (up to five or six months), the demand probability is considered to be adequate for use.

5.2.4.5. Source independence

The IREP data base and the data base from NUREG 2815 are heavily interdependent, because one draws the data from the other. These two sources should be used one at a time; they should not be mixed. Other dependences commented on in the paragraph describing dependence of NUREG 2815 are also applicable here.
5.2.5. IEEE Standard 500

5.2.5.1. General

The IEEE Standard 500 included in the IAEA data base is the 1984 edition, which is a follow up to the first, 1977 edition of the Standard. IEEE 500 is the richest source of information considered in the IAEA Data Base. It provides reliability data for electrical, electronic and sensing components, as well as for mechanical equipment. The data contained in it are intended for the use of either nuclear system reliability analysts or design engineers.

5.2.5.2. Data sources

IEEE Standard 500 draws data from a variety of sources. As it is a follow up to the 1977 edition, some of the data come directly from there. Among the other sources, the most important are:

(1) Corps of Engineers (HND) R/M Data Base, Ground Stationary Equipment, Rep.No.16, 04/12/73

(2) Non electric Parts Reliability Data (NPRD-2), Summer 1981, Reliability Analysis Center, Rome Air Development Center, Griffiss Air Force Base, NY 13441.3


All the NUREG/CR publications providing reliability parameters derived from IER reports (NUREG/CR 1205, 1331, 1363, 1740) are also included here. Also included is the NUREG/CR 2886 IPRD report on pumps.

In addition, a number of other reports providing data about particular components as well as some of the in-plant sources and architect-engineer companies provide input for the IEEE 500.

The data for some of the component categories (annunciator modules, batteries and chargers, circuit breakers, relays, motors and generators, heaters, transformers, valve operators, instruments, controls and sensors and conductors) partly resulted from the analysis of estimates made by over 200 experts. The collection of expert opinions was performed by the extensive multistep DELPHI method. (The Delphi method is a formal way of collecting information by establishing a feedback system for written communication of data and information among the group of professionals. Detailed information about the method and its use can be found in IEEE 500 (1984), Appendix B and elsewhere.) It is important to mention that individual experts were instructed to estimate data only when statistical sources of data remained unavailable to them. In some cases, the data developed (for respective categories) represent either recorded data or the best collective judgement of a group of specialists.

To summarize, the raw data from which the values appearing in the IEEE 500 were synthesized were found in the following forms:
1. Statistical operating data from nuclear power plants

2. Statistical operating data from fossil fired generating stations and other data from large industries (such as the chemical industry)

3. Statistical failure data from transmission grids and industrial plants, with use of judgement to estimate the population from which the failures were observed so that a failure rate could be calculated.

4. Data on failure and population estimated by individuals familiar with the operating and failure histories of specific generic types of devices.

5. Data extracted from published sources for other industries which were judged to have some level of applicability to components of nuclear power generating stations.

It is stated that on the average 80% of the data included in the IEEE 500 resulted from statistical data in one of the first three categories mentioned above.

5.2.5.3. Data available in the IAEA Data Base

IEEE 500 provides the data for a variety of components found in NPPs. Intended use of data from the IEEE 500 is in the area of general reliability calculation and not PSA studies in particular. Therefore the level of detail is much greater than elsewhere.

The IEEE 500 utilize a hierarchical structure to group component in categories. The broadest hierarchical breakdown is 'chapter', which identifies a general component category (example of 'chapters' are transformer, driven equipment and conductors). There are 17 chapters and respective component categories included in the IEEE 500. The second breakdown level is called 'section'; the division into sections is based on functional or physical differences between components. The third level, when present, is called 'subsection'. The 'item or equipment' description is the last hierarchical level. It can be either third or fourth level, depending on the existence of "subsection" level.

For each data entry there is a failure mode defined. In general, failure modes are divided into three categories: catastrophic, degraded and incipient failures. These categories are sometimes subdivided into the more detailed modes, which heavily depend on each component category. All three categories are summed together under the 'all modes' numerical value. Detailed discussion of the failure mode is provided in Appendix A and in the preface of each data chapter of IEEE Standard 500.

IEEE 500 provides single data entries, but also the composite values on the hierarchical levels where the composite value provides a certain overview.

Failure rates are presented with three data points: recommended value, high value and low value. The recommended value should be used to determine the best estimate. The high and low values represent best and
worst data points and can be used as a range estimate (usually they should not be interpreted as specific confidence bounds). Two types of data are found in the IEEE 500. One is failure rate in terms of failures per $10^6$ hours, and the other is in terms of failures per $10^6$ cycles. The cyclic failure rate is used in specific instances to describe demand probabilities. Some of the data entries provide recommended values only.

In addition to failure rates, the outage times are sometimes found in the IEEE 500 data sheets. Outage times are divided into three categories: out of service duration, restoration time and repair time. Consistently with the failure rates, recommended, high and low value (representing the highest and lowest data points) are presented.

The IEEE Standard 500 provided about 180 records for IAEA Data Base. These 180 records cover the whole spectrum of components found in NPPs and usually taken into account in PSA studies. Most of the records in the IAEA data base come from the identifiable ultimate data source that seems to be the most applicable for PSA use. In several cases, where deemed appropriate, composite values were included to give the user an illustration of the expected range of data. In all cases the comment lines provide information about the data.

Failure modes considered where those which are of interest for PSA studies. In most cases these are catastrophic failure modes and in a few cases degraded failure modes. Whenever available, the failure rate is given for precisely defined failure modes (for example, a short to ground). Sometimes the failure rate is given for catastrophic (or degraded) mode and in comment lines it is stated what is being considered in that failure mode. For some of the components only the 'all modes' failure mode was available without indication of the proportion of catastrophic, degraded and incipient failures in the total. If the component was considered to be of major interest for PSA studies, it was then included in the IAEA Data Base.

For uniformity throughout the data base, the failure rates and demand probabilities are presented as per hour and per cycle (being equivalent to per demand) values, respectively. Whenever available, the repair time for a particular component was included in the IAEA Data Base. The repair time in the IAEA data base is always the recommended value from IEEE 500.

5.2.5.4. Special features

The IEEE 500 draws information from a variety of sources, so the failure data are for the items and conditions discussed in the individual sources.

The special feature of the IEEE Standard 500 is an environmental factor matrix provided for the number of components included. The multipliers for high temperature, humidity and radiation are taken from the 1977 edition of Standard. They are not included in the IAEA Data Base.

5.2.5.5. Source independence

As mentioned, IEEE 500 contains several sources which are also individually included in the IAEA Data Base. In addition, other sources providing operating experience at US NPP's draw the information from the
same population of plants (although in a different manner), so the data points are not statistically independent.

Some of the data points originating from expert opinion also cannot be considered independent. Although they are collected by use of the Delphi method, bias in expert opinion should be properly considered.

Some of the other sources in the IAEA Data Base also use the IEEE 500 data for priors in Bayesian updating (Oconee PRA, for example). In these cases dependences should be properly considered.

5.2.6. Shoreham Nuclear Power Plant PSA

5.2.6.1. General

At the time of the PSA study for Shoreham NPP, no operating history was available, thus several sources of generic BWR operating experience were used to provide a surrogate basis for failure data. Among several data sources considered in the study, of special interest for inclusion in the IAEA Data Base was the General Electric collection of operating experience.

General Electric has collected and evaluated BWR operating experience data on a wide variety of components to estimate their failure rates. This source is pertinent to BWRs and lists specific components on which data are not usually available elsewhere.

5.2.6.2. Data sources

Detailed information about the ultimate data source as well as about the methodology used to evaluate data and derive reliability parameters is not available. It is clear that GE collected operating experience, but it is not clear whether it was in the form of licensee event reports (LER) or otherwise.

5.2.6.3. Data available in the IAEA Data Base

The complete set of GE data available from the source was included in the IAEA Data Base. That is about 25 records, containing mean failure rates for valves (MOV, check, ADS valve), pumps, motors, heat exchangers and a variety of instrumentation and control equipment.

5.2.6.4. Special features

The same set of GE data was used in the PRA study for the Limerick NPP, where the comparison between GE data, WASH-1400 data and data from the analysis of LERs (LER rates) was made. Many of the data from the three
sources are similar and there is generally good agreement between all three sources.

Another important feature of the GE data is the concept of treatment of demand related failures. The constant hourly failure rate is used for components in standby. The probability of failure is then calculated by multiplying failure rate by one half of the scheduled test interval (e.g. monthly, annually).

Quantification of the fault trees in the Shoreham PSA was done using four data sources, and in the following hierarchy:

1. LER rates
2. GE data
3. WASH-1400

5.2.6.5. Source independence

As the ultimate data source is not clear (in the sense of number of plants, the time interval covered and means of data collection) strictly defining the dependence is not simple.

The source is said to contain the data based on operating experience of GE BWR plants, and since these plants are also considered in estimation of LER rates, there is relatively high dependence between this source and NUREG documents with LER rates.

This is also the case with IPRD (In-Plant Reliability Data, NUREG/CR-2886 and NUREG/CR-3831) sources, which contain data drawn from operating experience of a couple of BWR plants.

5.2.7. NUREG/CR 4550 Vol.1, Analysis of Core Damage Frequency From Internal Events: Methodology Guidelines

5.2.7.1. General

NUREG 4550 Vol.1 summarizes the methodology for accident sequence analysis for reference plants examined as a part of NUREG 1150 program. Chapter VIII provide generic data base which was used when reasonable plant specific data were not available.

Generic data base in NUREG 4550 is the updated ASEP (Accident Sequence Evaluation Program) data base which was originally used to calculate accident sequence frequencies for 100 light water reactors. It was updated in April 1984 and June 1985. The last update occurred in August 1987 using information from the Risk Methods Integration Evaluation Program. Data in the IAEA Data Base comes from this last update.
5.2.7.2. Data sources

ASEP data base was formed from a broad information base. A number of PSA studies and other sources of information were reviewed and ranges established. Some examples of the sources that were used are the following:

- WASH 1400
- NUREG/CR 1659 Reactor Safety Study Methodology Application Program (all plant analysis)
- IREP Procedure guide and plant analysis
- Zion NPP PSS
- Oconee PRA
- IEEE Standard 500 1984
- NUREG/CR 3226 Station Blackout Accident Analysis, Sandia National Laboratory, May, 1983
- NUREG/CR 1032 Evaluation of Station Blackout Accidents at Nuclear Power Plants NRC, May 1985

5.2.7.3. Data available in the IAEA Data Base

The complete set of component reliability data provided in the source is included in the IAEA Data Base. The source provide about 20 records, addressing components like pumps, valves, DGs, batteries etc.

ASEP data base provide two parameters for each component, mean value and log normal distribution error factor. Although several sources were reviewed for each component, the mean value is always taken from a single source which is then identified in the comment lines of each record. Also all additional information found in the original source are also included in the comment lines.

5.2.7.4. Source independence

As there is no operating experience behind this source, it is heavily influenced by all the sources which were reviewed. Practically all available US data sources were used in compilation of ASEP data base. Therefore this source should be considered greatly dependant to all of the others.

5.2.8. NUREG/CR 4550 Vol.3 Surry NPP

5.2.8.1. General

NUREG/CR 4550 is the document containing the accident sequence analysis for Surry Unit 1 NPP. This is one of the reference plants being examined as part of the NUREG 1150 work, which will document risks for selected group of nuclear power plants.
The accident sequence quantification was performed using generic as well as plant specific data. For inclusion in IAEA Data Base only the plant specific data were of interest. There are 10 data records from this source in the IAEA Data Base.

5.2.8.2. Data sources

The ultimate data source is plant operating experience. Whenever plant specific operating experience was sufficient (or where potential plant specific common cause failures were identified), these data were used for quantification. However, it is not clear what kind of in-plant records or other means were used to derive information. It is difficult to judge about the quality of the data or the operating experience behind them.

5.2.8.3. Data available in the IAEA Data Base

The complete set of plant specific data provided in the source was included in the IAEA Data Base. The data cover different kinds of pumps, diesel generators and strainers.

The failure rate given is a median value together with an error factor (assuming lognormal distribution). Failure rates are defined as per hour values, while starting failures are defined as per demand probabilities.

5.2.8.4. Special features

The failure mode for auxiliary feedwater pumps (motor and turbine driven) is called ‘failure to start/run’ and is defined as per demand probability. It was not possible to identify the eventual mission time associated with this failure mode. It is unclear what proportion of the failure probability to assign to starting failure and what (if any) to running failure.

As with other sources of this kind (PSA studies), the component boundary is not strictly defined, but can be assessed in accordance with the fault tree entry.

The operating mode found in the IAEA Data Base was determined in accordance with the function of each component.

There was no indication either of the operating environment of the components listed. However, a normal nuclear power plant environment was assumed.

5.2.8.5. Source independence

As is the case with other US sources which draw data from a single plant (or group of plants), there is a relatively high dependence to LER
rates, because each US nuclear power plant is contributing to the IER system. The level of dependency is difficult to assess without knowing the ultimate source of data at the plant.

5.2.9. Sizewell B PWR Preconstruction Report

5.2.9.1. General

This report provides a list of component failure rates that were used in the safety assessment of the proposed PWR nuclear power plant at Sizewell in the UK. The data used for safety assessment were assigned to each component and failure mode based on an overview of several data sources.

The items which were identified as having the highest contributions for the failure probability of the safeguards systems were the following: non-return valves (check), relief valves, M3Vs, pneumatic valves, pumps (motor and turbine), diesel generators, fan coolers and circuit breakers. For each of these components appropriate failure modes were assigned.

5.2.9.2. Data sources

Several data sources were used to assess failure rates. These were:


2. UKAEA System Reliability Service, which provides a comprehensive review of reliability information and provides generic data for use in safety and availability assessment. Many of the data relate mainly to typical industrial applications.

3. WASH-1400, Reactor Safety Study.


It should be noted that the ultimate data sources are a variety of sources of information, coming from different areas and collected in different ways. However, it seems that no formal statistical data assessment procedure was used to obtain failure rates. Engineering judgement seems to be utilized for that purpose.

Data from source No.1 (Westinghouse) are proprietary, and were not available, so it is difficult to judge which data source most influenced the assessed failure rates.
5.2.9.3. Data available in the IAEA Data Base

The full set of data available in the source is reproduced in the IAEA Data Base. Component failure rates and demand probabilities are mean values.

In addition to the data utilized in calculations, every record of the IAEA Data Base originated from this source contains all the available information which served as a basis for failure rate determination. The ultimate source of the data as well as the particular values are included in the comment lines of every record.

Altogether there are 22 records in the IAEA Data Base drawing information from this source.

5.2.9.4. Special features

There is no component boundary definition included in the document. As the purpose of the report was to provide data for preliminary calculations detailed component boundary definition is not necessary.

The operating environment is considered to be a normal power plant environment, except for the fan coolers, for which it is stated that failure rates are applicable to fan coolers operating in a post-LOCA/SLB (Loss of Coolant Accident/Steam Line Break) environment.

5.2.9.5. Source independence

One basis for failure rate assessment was the Westinghouse data base. It is assumed that this data base takes into account the subset of failures considered in the LER rates in NUREG documents.

Also, WASH-1400 is one of the sources considered in the failure rate assessment, so partial dependence will have to be considered here.

However, as failure rates are not assessed by any formal method, and it is not clear which source most influenced the process, some of dependence mentioned could be negligible.

Some of the records in the IAEA Data Base provides data from UKAEA SRD. This values are applicable either to PWR reactors or to general industrial use. Data items characterizing industrial use can be considered completely independent of all the other data in the IAEA Data Base.

5.2.10. Oconee Nuclear Power Plant PRA

5.2.10.1. General

In the Oconee PSA much effort was put into the development of the data base. The data base was developed according to Bayesian methodology to
combine generic information (obtained from industry experience) with plant specific data from the Oconee plant records.

Plant specific failure data were combined with generic failure rate distributions using the one stage Bayes theorem. Although the generic prior data used were discretized truncated log normal failure rate distributions, the updated distributions are not necessarily log normal and should not be considered as such.

The mean values of the updated distributions were used to quantify the system and sequence models. The discretized form of updated distribution (which is the direct output of the updating process) was used in the propagation of the uncertainty for the dominant cut sets of the dominant sequences identified in the analysis.

5.2.10.2. Data sources

The first step in developing the database was development of the generic data base. After defining components and failure modes for which data were needed, all available data were thoroughly reviewed, analyzed and tabulated.

The generic failure rate distributions developed for Oconee PRA contain, in each case, the range of information embodied in the literature. Each distribution was presented as a lognormal distribution.

The median value of each distribution was almost always taken directly from one of the published data summaries. The range factor (ratio of 95th percentile to the median) was in most cases subjectively assigned. The 5th and 95th percentiles of the distribution represent realistic bounds for expected or observed component failure rates.

Plant specific failure data were derived from three in-plant sources, namely:
- Work requests (WR) written whenever maintenance is required on any piece of equipment in the plant;
- Incident reports (IR), prepared for any event that may be a candidate for license event report to the NRC or for other utility purpose (in general, IRS are written only for events affecting the systems or equipment addressed in Technical Specifications);
- Licensee event reports, which are actually condensed versions of IRS.

These information sources were analyzed for the period 10 January 1975 to 30 June 1980. Each of these sources has its unique advantages and disadvantages. Further explanation of these aspects can be found in Oconee PRA, Chapter 5.1.

In addition to data on failures, information on success as well as operating time and number of demands was needed. Sources which provide failure data do not provide information about successes. For the component demand data, periodic test reports and the control room operating logbooks
were the most important sources. Component service hours needed to develop plant specific time related failure rates, were derived from records of annual operating times for large motor driven components, normal plant operating procedures and system lineups and periodic tests.

5.2.10.3. Data available in the IAEA Data Base

Practically all the data given in the Oconee PRA are reproduced in the IAEA Data Base, making 54 records.

The values appearing in the records are the mean, the 95th percentile and the 5th percentile of the updated distributions for the failure rate, the upper bound and the lower bound, respectively. In addition, in the comment lines, information regarding generic prior (the exact source of the mean and respective distribution percentiles) together with recorded plant experience (number of failures, number of demands or operating time) is provided.

Some of the records also contain the repair times. The repair time is usually the mean of updated maintenance durations for particular components as found in Table 5.5 of the Oconee PRA.

5.2.10.4. Special features

The definitions of the components and their boundaries do not exist in the formal sense. However, the component boundary can be directly assessed from the fault trees.

Neither was any information found about environmental effects and applicability of failure rates to different component environments. Normal nuclear power plant environment was considered instead.

Some of the records in the IAEA Data Base contain information about component operating modes drawn from knowledge of the usual operating mode for particular components. In most cases 'all' operating modes were considered.

5.2.10.5. Source independence

As one of the data sources for the Oconee plant specific failure data was LER reports, there is a certain interdependence with LER rates (NUREGs).

Data included in the IAEA Data Base are products of an updating process, so dependence on the prior is obvious and in some cases extreme (where operating experience is sparse). As the generic distribution was developed for each component in question, it is not generally possible to indicate dependence on particular generic sources; this should therefore be assessed on record by record basis. As mentioned, each record contains information about prior (mean value and distribution percentiles) uses in the updating process.
5.2.11. Old PWR reactor

5.2.11.1. General

Under this name is a data base compiled by updating the generic data with plant specific operating experience. This source was useful for inclusion because it contains rather extensive plant specific operating experience.

This data source provides very detailed component divisions, especially in some of support systems rarely found in PSA studies.

This data has been compiled by the IAEA in the framework of various activities (workshops, technical assistance missions etc.) and therefore its accuracy cannot be verified.

5.2.11.2. Data sources

Plant specific operating experience was extracted from the plant operating records.

5.2.11.3. Data available in the IAEA Data Base

This source provided more than 110 records to the IAEA Data Base. Each record contains mean value and 95th and 5th percentiles of the updated failure rate distribution. Comment lines of each record provide information about the mean of generic distribution which was used as a prior in updating as well as the exact number of component failures and number of demands or the operating time recorded (or assessed).

Some of the records provide repair times, which are usually the mean of the maintenance duration.

5.2.11.4. Special features

The special feature of this source is the availability of failure rates for support systems like heating, ventilation and air conditioning (HVAC) components, different compressors, etc.

No detailed component boundary descriptions, or information about operating mode or environment was available. In some of the records the component operating mode was assessed from knowledge of the particular components function in the NPP.
5.2.11.5. Source independence

Plant specific data are completely independent of all the other sources in IAEA data base, and the failure and success data provided in the comment lines can therefore be used as statistically independent evidence.

Generic data used as the prior in updating process are dependent to other sources in the IAEA Data Base, but it is not possible to assess the magnitude of dependence.

5.2.12. Heavy Water Reactor (HWR) assessment

5.2.12.1. General

The source included in the IAEA Data Base under this name provides data compiled from accumulated operating experience. This is the second largest source in the IAEA Data Base, yielding more than 150 records. The source gives a rather detailed division into component sizes (valves) and functions (pumps). The total amount of operating experience used to assess failure rates is substantial.

This data has been compiled by the IAEA in the framework of various activities (workshops, technical assistance missions etc.) and therefore its accuracy cannot be verified.

5.2.12.2. Data sources

The ultimate data source is operating experience assessed from the comprehensive overview of the plant records. In a few cases details of operating experience are not given, and these data may be assessed on the basis of engineering judgement.

5.2.12.3. Data available in IAEA Data Base

The data on each component found in the source are reproduced in the IAEA Data Base.

As mentioned, there are more than 150 records from this source in the IAEA Data Base, addressing about 70 component types divided into mechanical, electrical and instrumentation and control categories. For most of the component mean values, 95% and 5% confidence limits are included.

Also, a factor (called in the source error factor) indicating the ratio between the 95th percentile and the median is given in most of the records (in all records having confidence limits in the original source).
The mean time to repair is given for most of the components and in most of the cases it is the actual recorded time; however, in some cases it was conservatively estimated.

The comment lines of each record form provide information about the total population considered, the cumulative component operating time and the number of failures recorded. If the failure mode is 'all modes', usually in the comment lines it is stated which failure modes are considered under 'all modes'. Characteristics of the contribution of each particular failure mode to 'all modes' in terms of dominant or negligible contributions are also provided in the comment lines.

5.2.12.4. Special features

One of the special features of this source is the cumulative failure mode 'all modes' which simply adds several single failure modes in the cases where breakdown was possible. Usually out of five failure modes considered under all modes, two or three are significant, while the others are practically negligible. An 'all modes' failure rate is, therefore always provided, together with failure modes having significant failure rates.

For some of the components (for example pumps classified according to their function) the source does not provide a breakdown into detailed failure modes; only 'all modes' failure rate is therefore provided in the IAEA Data Base.

All failure rates are given as per hour values.

In the original source, failure rates were given as occurrences per 1000 component operating years. To be consistent in the IAEA Data Base, failure rates are presented as per hour values.

This source also has rather detailed division into categories according to dimension (valves). However, details about component boundaries were not available.

The operating mode and environment are also not known, so all operating modes and normal power plant environment is considered throughout.

5.2.12.5. Source independence

This source is considered to be completely independent of all the other sources in the IAEA Data Base.

5.2.13. Zion Nuclear Power Plant PSS

5.2.13.1. General

This source is the data base compiled from Zion NPP Probabilistic Safety Study. It consists of generic data updated with plant specific
operating experience. Almost the full set of data found in the source is reproduced in the IAEA Data Base.

5.2.13.2. Data sources

The generic sources used as the priors in updating were WASH-1400, IEEE 500 (1977) and NUREG documents.

The mean values for most of the pumps, valves and diesel generators were taken from NUREG documents. The population variability was obtained by taking the 95%/5% ratio from WASH-1400 as the 80%/20% ratio for the generic distribution. This approach broadens the original WASH-1400 distributions substantially.

The data for electrical, electronic and sensing components were taken from IEEE 500 (1977). The 'recommended' value from IEEE 500 was taken as the median, and the 'maximum' value as the 80th percentile of the population variability curve. These two values were used to generate the 20th percentile.

In some cases where there were no applicable data in NUREGs or in the IEEE 500, the WASH-1400 5th and 95th percentile values were used as the 20th and 80th percentiles of the population variability curve.

The primary source of component failure data used for updating was the licensee event reports. A compilation of all LERs submitted by Zion NPP 1 and 2 from initial criticality (20 June and 25 December, respectively) to December 1979 provided the basic event description from which the corresponding failure rates were assessed.

A number of other sources were used for specific items requiring more detailed information than was available in LERs. These sources included control room logs, component maintenance records, testing records and internal event reporting documents (deviation reports).

The operating time or number of demands corresponding to the failures derived from the aforementioned sources were assessed from the operational history, considering total time, time on power, number of tests in accordance with the technical specification, etc.

5.2.13.3. Data available in the IAEA Data Base

Zion PSS provide 38 records to the IAEA Data Base. All the data points except those for which no plant specific data exist were included in the IAEA Data Base.

The failure rate values included in the IAEA Data Base are updated mean values.

The comment lines of each record contain information about the exact prior used in updating for particular components, including source and exact failure mode (if different than failure mode in Zion data base). In the cases where the prior mean and the variability ranges were taken from different sources, information on both was included.
Plant specific information regarding the operating time or the number of demands and the corresponding number of failures is also provided in the comment lines of each record.

5.2.13.4. Special features

As with the other sources that are PSA studies, component boundaries are defined in fault trees.

The operating environment is not clearly stated and the normal power plant environment was assumed for all records.

5.2.13.5. Source independence

This source is highly dependent on its priors (WASH-1400, IEEE 500 and NUREG documents) for respective components.

As the sources of plant specific data are plant LERs, there is an additional dependency to the NUREG documents which draw the raw data from LERs.

5.2.14. NUREG documents with LER rates

5.2.14.1. General

In the IAEA Data Base there are four sources based on the raw data drawn from LER reports in the USA. These are:

1. NUREG/CR-1205, Data Summaries of Licensee Events Reports of Pumps at U.S. Commercial Nuclear Power Plants EG&G Idaho, Inc., January 1982


All these sources have common characteristics and therefore are treated together.

The common characteristic of these sources is that the ultimate data source is the operating experience of group of plants, collected through the Licensee event report system. The population size, operating time or
number of demands needed to evaluate recorded failures statistically, was judged from the information available.

Because of the process of judgement involved, the component failure rates estimated should be interpreted as only tentative gross indicators of the true failure rates. It is necessary for the individual analyst to validate the applicability of the LER derived failure rates in each case separately.

5.2.14.2. NUREG 1205

NUREG/CR-1205, providing rates for the pump components drew information from LERs from 1 January 1972 to 30 September 1980. In that period a total of 1103 pump faults were discovered. Of these, 552 faults were classified as pump failures, while the remaining 551 were identified as command faults.

For the purpose of the report the pump component is defined as the pumping unit, prime mover, coupling and associated mechanical control. All the failures in this category are considered to be pump failures, while any fault outside this boundary is considered to be command fault.

In this source pumps are classified according to their prime mover (motor, turbine or diesel driven) and by operating mode category (running, alternating and standby). Operating mode category is assessed on the basis of the system to which the pump belongs. (Detailed definitions of boundaries and an explanation of operating modes can be found in the source.)

NUREG/CR-1205 define four failure mode categories: 'leakage/rupture'; 'does not start'; 'loss of function' and 'does not continue to run'.

The final LER rates from this source are standby failure rates, operating failure rates and demand failure rates, calculated as failures per hour or per demand. Operating rates were estimated for 'leakage/rupture', for 'loss of function' and for 'does not continue to run'. Standby rates were estimated for the failure mode 'does not start'. Operating LER rates were estimated as the aggregation of failure modes 'leakage/rupture', 'loss of function' and 'does not continue to run'.

All LER rates were calculated with and without command failures (except for 'leakage/rupture' for alternating pumps).

In addition to LER rate estimate, multipliers for 95% and 5% confidence limits are given for most data points.

Data available in the IAEA Data Base

There are nine records containing information from this source in the IAEA Data Base.

As the failure modes 'leakage/rupture', 'loss of function' and 'does not continue to run' were aggregated in original source, only the aggregate value was included in the IAEA Data Base (it was felt that only this is of importance for PSA uses).
Each record from NUREG/CR-1205 in the IAEA Data Base contains the LER rate estimate (point value) and the upper and lower bounds calculated from mean value using multiplication factors. All values do not include command faults.

In the comment lines of each record the respective population and number of failures used to calculate LER rates are given. The respective LER rates with command faults are also included in the comment lines.

LER rates for failures to start are given in failures per demand. When available, failure rate in terms of number of failures per hour standby are also given in the comment lines.

5.2.14.3. NUREG 1331

The LER rates on control rods and drive mechanisms (CRDM) were derived from events between 1 January 1972 and 30 April 1978. In that period 504 failures were discovered.

Control rod and drive mechanism was defined as the control rod, the drive mechanism (electric for PWR and hydraulic for BWR), the housing containing the drive mechanism and all parts connecting the control rod to the drive mechanism. The cables or piping external to the drive mechanism were not considered to be part of the CRDM.

Altogether, 12 failure modes were identified during the LER search. Six of these were considered to be relevant and were included in the IAEA Data Base. These are: 'failure to insert at least 96% during scram'; 'failure to inset during normal shutdown'; 'fails to move during power changes/testing'; 'dropped rod'; 'uncoupled/overtravelled rod' and 'improper rod movement'. The first three of these are defined as failure per demand; others are defined as failures per hour standby.

Data available in the IAEA Data Base

This source provided 10 records to the IAEA Data Base. Each record contain the LER rate mean value as the failrate and 95% and 5% confidence bound as the upper and lower bound, respectively.

Generally, the rates are without command faults. Whenever available, rates with command faults are provided in the comment lines. When the failure rate is defined in numbers of failures per demand, the standby hourly failure rate is provided in the comment lines.

5.2.14.4. NUREG 1363

Failure rates in this source were derived from LERs submitted between 1 January 1976 and 31 December 1980. The total number of events considered failures or command faults in that period was 4209. Of these, 3233 events were considered to be failures, while the other 976 were considered to be command faults.
Seven categories of valves were considered for LER rate assessment. These are:
- motor operated valves;
- remote operated plus motor operated valves;
- air operated valves; check valves;
- manual operated valves;
- safety valves (FWR) and
- relief valves (BWR).

Of these, 'remote operated plus motor operated valves' is a special category. Some of the LERs did not specify the valve type, but provided information to permit their classification as remote operated. As most of the remote operated valves in safety systems are motor operated, it is believed that most of the failures reported are actually failures of motor operated valves. Therefore, this category should be a more realistic representation of LER rates for motor operated valves.

From the LERs, 11 failure modes were identified for valves. Detailed descriptions and definitions of each of them are found in the source.

For the purpose of deriving LER rates, the valve component is defined as the valve body and all its internal parts, the valve operator and any attached functional accessories (e.g. limit or torque switch) that are needed to make the entire assembly functional. Supply systems to the valve operator (such as electrical, air or hydraulic) are considered to be outside the bounds. Failures involving supply systems are considered to be command faults to the valve assembly.

For most of the valve categories and failure modes, LER rates with and without command failures are provided.

Data available in the IAEA Data Base

This source provides 17 records to the IAEA Data Base, addressing all valve categories except motor operated valves. As mentioned, the category 'remote operated and MOV' better represent MOV failure rates, and it was included as motor operated valves.

The LER rate is given in each record as the failrate, while 95% and 5% confidence limits are given as the upper and lower bound, respectively. The rates given are without command faults.

In the comment line of each record the LER rate with command faults is given. In cases where the LER rate is defined as per demand value, the standby hourly rate (when available) is also provided.

In most cases the overall rate is given (all vendors). Where it seemed to be important, FWR and BWR rates were distinguished.

5.2.14.5. NUREG 1740

NUREG/CR-1740 is a summary of the evaluation of LERs submitted between 1 January 1976 and 31 December 1981 that pertain to electrical and
electronic components in instrumentation and control systems. Owning to the limited availability of the component population, IER rates were estimated only for I & C components that are parts of the channel that performs the reactor trip. In this period 6764 faults were found; 6180 were classified as actual failures while the rest were identified as command faults.

IER rates were estimated for the following components:
- sensors;
- transmitters;
- signal conditioning systems;
- comparators and bistables;
- switches and radiation monitors.

Also the major components of analog systems were combined, depending upon the parameter they were monitoring, to form the instrument channel. IER rates were then estimated for the following analog instrument channels:
- nuclear core flux;
- temperature;
- flow;
- level and pressure.

In the digital systems, switches were considered a channel and IER rates were estimated for level and pressure/vacuum switches.

Two failure modes were assessed for each component: reduced capability and inoperable. Reduced capability failure mode describes an event where the component is operational, but does not perform its function within defined limits. Example of these events are instrument drift, out of calibration or spurious operation.

Data available in the IAEA Data Base

This source provide 28 records to the IAEA Data Base. Half describe single components, while the rest provide instrument channel data. IER rates (point estimates) are found in the failrate line, while 95% and 5% confidence limits are given in upbound and lowbound, respectively. Contrary to other IER sources, point estimates and confidence limits from this source include command faults.

In the comment lines of each record, the failure rate point estimate without command faults is given.

5.2.14.6. Source independence

All NUREG IER rates sources draw raw data from plant experience. In terms of statistics they are completely independent.

Several sources included in the IAEA Data Base use failure rates derived from IER as a prior in data updating process. Interdependence in those cases is obvious.
5.2.15. The In-Plant Reliability Data Base (IPRD) for Nuclear Plant Components

5.2.15.1. General

There are two sources from IPRD in the IAEA Data Base. These are:


The objective of the IPRD was to develop a comprehensive, component specific data base for probabilistic risk assessment and for other statistical analysis relevant to component reliability evaluation. Contrary to IER rates, the primary sources of data were in plant maintenance files, including all corrective maintenance actions on each component.

5.2.15.2. NUREG 2886, the pump component

Failure rates for the pump components were derived from maintenance and repair records from six NPPs (two PWR and four BWR) providing 27 reactor years of experience. About 4000 records were collected. The total population of all pumps is about 1500.

From data collected, point estimate and confidence limits (95% and 5%) were calculated for time and demand related failures.

The approach taken when defining the pump boundary considers a 'super' component or pumping function. It means that failure of the pump component includes failures of pump impeller, shaft, motor, local switches and instrumentation and control circuitry. Command faults (such as loss of steam) are considered to be outside the boundary.

The pump population was divided according to operating mode (running, alternating and standby) and driver (motor driven, turbine driven and diesel driven). Point estimate failure rates and the ranges were assessed for each of these.

Data available in the IAEA Data Base

This source provided seven records to the IAEA data base. In the IAEA Data Base failure rates are given in form of point estimate and upper and lower bounds in form of confidence limits. In the comment lines information regarding population size, number of failures and total operational time or number of demands are included.

Normal nuclear power plant environment was assumed for all records.
For these components, about 700 relevant maintenance and repair records from five plant were collected, covering a time-span of 33 years.

The components considered are defined as having the following boundaries:

DG: general criterion is to include local systems and components that are integral to starting and sustaining the electrical generating capability of the diesel generator. Detailed description of interface points are to be found in the original source.

Battery: the boundary is defined to include the battery container, the seismic design battery rack and straps, internal parts including plates and electrolyte, terminal connections including cables with lugs, posts or connectors, and any switches or meters for the normal operation of the battery.

Battery charger: (only static battery chargers are included) the boundary is defined to include the connecting feeder breaker to the alternating current (AC) source (motor control center or bus) and the connecting output breaker to the direct current (DC) bus. Included in the boundary between these two points are the electronic and non electronic components within the charger enclosure, and the associated instrumentation, control and protective devices, including meters, relays, fuses, switches and circuit breakers.

Inverter: the boundary is defined to include all electronic and non electronic components within the inverter unit, the rectifier, the static transfer switch, associated instrumentation and local control and protective devices (meters, relays, fuses, switches and circuit breakers).

All the failures in the source were divided into three categories in accordance with the failure severity (catastrophic, degraded and incipient). Only catastrophic failures seem to be interesting from the point of view of PSA analyst.

The source provides aggregate failure rates as well as the plant specific failure rates. For the IAEA Data Base only the aggregate rates were of interest because of the relatively short operating periods and the sparse failure data for single plants.

A special feature of this source is the definition of DG failure modes. The failure mode 'failure to start' includes an initial running time of 30 minutes, because it was considered that 30 minutes is the time needed for the DG to warm up. This source also uniquely defines the DG running failure mode by splitting it into two categories, namely 'failure
to run once started' and 'improper operation'. The first includes all failures which prevent the DG from continuing to run after initial 30 minute warm-up period. The second one is used to cover cases where the DG was tripped owing to local problems (running hot is one example), but in emergencies it would continue running. The source suggested that combining these two would allow the comparison of the failure rate with failure rates for DG failure to run found in other sources.

Both of the DG running failure rates are included in the IAEA Data Base. They are marked with an asterix to indicate that they are not comparable with other sources. An additional record combining these two is also provided.

Data available in the IAEA Data Base

This source provided eight records to the IAEA Data Base. Each record contains recommended failure rates (or demand probability) value, and high and low value as the upper and lower bounds, respectively. Some of the records contain repair times which are ranges of recorded medians.

The comment lines of each record contain information regarding the population observed, the number of recorded failures and the corresponding number of demands or operating times.

5.2.15.4. Source independence

There is moderate interdependence between this source and NUREG LER sources because in a number of cases the same failures are accounted for in both.

5.2.16. EPRI NP-2433, Diesel generators data

5.2.16.1. General

The objective of this project was to provide high quality data on diesel generators for use in risk assessment. What makes this source interesting for inclusion in the IAEA Data Base is the methodology and sources of raw data.

5.2.16.2. Data sources

The raw data were collected from a variety of sources, including:

-utility supplied accounts of diesel start attempts and failures;

-data obtained by project personnel through on-site inspection of plant operator logs, test records and maintenance logs;
-data collected from four plants by IEEE personnel through review of plant maintenance records.

- In addition the licensee event reports were searched for supporting information.

For starting failures, data from 13 nuclear plants were used, representing 123 diesel years, with 6910 demands. Running failures were calculated for two plants (three reactors) only.

5.2.16.3. Data available in the IAEA Data Base

Only two records in the IAEA Data Base are drawn from this source. One is the aggregate value for DG failures to start (13 plants), which is represented as a point value. The second is the failure to run calculated for Peach Bottom 2 & 3 plants, and, in addition to the point value, 95% and 5% confidence limits are given.

The exact number of demands and related failures as well as the population size are given in the comment lines.

5.2.16.4. Source independence

This is the only source in the IAEA data base which reflects DG operating experience of the population of US plants. Therefore it can be considered independent of all the other sources except Zion NPP PSS and IEEE 500 which are partially based on data from the same population.

5.2.17. The German Risk Study (phase A)

5.2.17.1. General

The principal objective of the German Risk Study was to assess one of the German nuclear plants using the WASH-1400 methodology. Originally it was intended to use the failure rates and probabilities from WASH-1400, but later, owing to certain differences, a set of data for exclusive use was developed.

5.2.17.2. Data sources

Three sources were used to obtain the reliability data for the study. These were:

- review of the relevant literature
- review of operating experience from NPPs Biblis and Stade
- failure effect analysis for part of the I & C component.
Weighting factors for each of the data sources were assessed from the available information for each component.

The components for which the data were assessed are not defined in detail to accommodate differences in design, operational and other parameters.

Log normal distribution was used throughout the study for the failure rates of components.

5.2.17.3. Data available in the IAEA Data Base

This source provided about 36 records to the IAEA Data Base. Each record has either a mean or a median value and the error factor associated with it. Comment lines usually provide more detailed information on the ultimate source of data.

5.2.17.4. Source independence

Failure data which originated entirely from operating experience of German plants are independent from all other sources in the IAEA Data Base. Failure rates obtained by literature review are in many cases based on similar sources as WASH-1400 failure rates. In this case the dependence is rather high.
6. PROBLEM AREAS CONNECTED WITH THE DATA BASES FOUND IN THE LITERATURE

When using a generic data base one has to be aware of possible problem areas. Considering the areas where misinterpretation can occur, the following 4 areas have been identified in the following order of importance:

- component boundary definition
- failure mode definition
- operating mode definition
- operating environment definition

Even when deriving failure rates from raw data from the plant being analyzed, these are issues which can lead to substantial errors.

During the development of the IAEA Data Base insights were gained in how different data bases address each one of these issues. These insights and possible ways of avoiding or solving such problems are addressed next.

6.1. Component boundary

It is obvious that a main source of misinterpretation is the component boundary definition. Some of the experts agree that variations in component boundaries are the primary reason for failure rate fluctuation between sources. Although that statement seems to be too rigid, component boundaries could, depending on the particular component, change failure rates substantially.

It is therefore interesting to see how different sources address this issue.

Probably the best defined component boundaries are in the Swedish Reliability Data Book, because practically each component category has a sketch exactly indicating the component boundary and points of interface with other systems or components. Usually, in the component boundary, local control and protection (if any) are included.

Some of the 'NUREG' documents also have adequately defined component boundaries, with precise definition of interface points.

Other sources are defining a component as being an "off-the-shelf" item. This is an interesting and remarkable definition, but it assumes that "off-the-shelf" items have the same meaning everywhere, what is not necessarily the case for all the components.

Data bases which are part of PSAs, usually do not provide detailed definition of the component boundary. This is understandable, because these sources were compiled for specific use. When performing data updating, component boundary gain importance because of the need for matching the prior with the plant specific operating experience.
The sources which base their failure rate upon the combination of nuclear and non-nuclear experience (or even expert opinion) do not provide detailed boundary description. The level of similarity of different sources combined is not known, but it can be expected that certain differences would exist.

For the sources mostly based on expert opinion, the question of strictly defined boundary becomes a more academic one. However, cases like lube oil being part of diesel or breaker included or not in a pump boundary must be addressed to avoid significant (orders of magnitude) variations in the failure rates.

One way of avoiding serious problems with component boundary definitions is to define 'generic' component boundaries. That, of course, does not help in already existing data sources, but could save considerable trouble in the future. However, this is mainly applicable to data collection efforts undertaken during the performance of a PSA. In that case component boundaries should reflect two, sometimes opposite, requirements: the level of detail needed (or wanted) by the system model and the level of detail of plant records where raw data are retrieved from.

There are generally three major interfaces to be defined in connection with the component boundary definition, namely:

- mechanical interface (incl. cooling system, lubricating system, etc. where appropriate)
- power supply interface
- control system interface

6.2. Failure mode

Component failure mode is another problem area, although of a different character than the boundary definition. Failure modes found in various sources show significant difference even when describing basically the same failure. For example, in the sources which were included in the IAEA Generic Data Base over 100 different failure modes were found. Difference between some of this failure modes is basically in wording (e.g. fail to run vs. failure to run) and it is therefore easy to understand that they describe the same failure. In other cases it is sometimes difficult to understand the exact failure mode and compare it among sources.

To compare failure modes and also to enhance the IAEA Generic Data Base coding system, considerable effort was undertaken to define generic failure modes.

Details about generic failure mode definition process as well as definitions for 18 major generic failure modes is found in Appendix 2.
6.3. Operating mode

Component operating mode is of importance for active components, while generally have much less meaning for passive components. Even for active components there are cases where the operating mode has more or less importance, depending primarily on the way and mechanism of how the failure occurs.

Obviously operating mode is of great importance for pumps and other components which perform their function by continuously moving. These components have operating modes defined in three categories:

- standby,
- alternating and
- running (operating).

For components which perform their function changing between discrete states, (e.g. valves), operating mode as defined above is actually status of the system they belong to. Operating mode pertinent to the component itself should be normally open or normally closed position.

The majority of the sources do not define the component operating mode. The only sources which define operating mode are some of the NUREG LER sources.

PSA studies used as the data sources usually define the system where the component is located. For most of the systems it is possible to determine the operating mode, what could be used for defining active components operating mode.

Although not directly connected with the operating mode, one very important characteristic which sometimes is overlooked is the duration of the operation. For standby components, if the failure rate is determined based on operating experience, it is based on recorded operation during test performance, what is usually one or several hours. In the real case, particular components are required to operate for times which substantially differ from the one which was the base for the failure rate determination. Most of the sources do not address that problem.

When modeling standby components, failures during standby must be accounted for. Failures occurring during standby are not revealed until a test or an actual component demand, therefore are usually included in the model as a demand related failure. In this cases the demand related failure should comprise those failures whose mechanism is purely related to the demand (e.g. high current to motor windings during start) and also failures related to the time which the component spent in a standby condition.

However, if data base provides only demand related failure rate without indication how long is the component in standby between two demands, this overlooks the fact that component failure during standby is time related and could vary substantially with variation in time between tests or actual demands.

Some of the sources recognized this fact and provide hourly failure rate for standby condition. On the other hand that approach is a possible source of error, because it is normally impossible to distinguish between time and demand related failures.
6.4. Operating environment

As mentioned earlier, the component operating environment is rather poorly defined in most of the sources. Most of the sources do not address it at all, while some of them are defining environment as the normal power plant environment. This definition could basically hold for normal operation or accidents which do not change environmentally affected parameters. However, when performing a PSA one is interested to predict the outcome of accident in environments, that could in certain cases change component failure rates substantially.

WASH 1400 is a source which provides separate failure rate for post accident situation for pumps and motors. The IEEE Standard 500 lists the environment multipliers for most of the components included, for environmental effects like high radiation, humidity, temperature and pressure.

Environmental effects could obviously affect component failure rate in different manners, therefore careful consideration should be given to this issue. Data from plant operating experience assume a normal environment, because operating experience data are normally either from normal operation or from test data, both of which are quite different from accident conditions.

On the other hand, the number and types of components affected by post accident conditions are usually rather limited. The extent of that is greatly dependent on plant design and type of accident.

Other type of extreme environment condition which can occur in NPP-s are high temperature condition occurring after the failure of room cooling systems. For most of electronic components or systems it is relatively easy and accurate to predict the effects of extreme environment and experimental data is available. For mechanical components like pumps, high temperature condition and consequently accelerated failure rates are relatively more complicated to predict.

6.5. Problems specifically related with in-plant data collection

In addition to the problems encountered in defining component boundaries and failure modes, the means of acquiring raw data at the plant have the greatest impact on the quality of the reliability data derived.

There are basically two sources for raw data at the plant. These are logbooks and maintenance work orders. Both have advantages and disadvantages.

Deriving raw data from the maintenance work orders is usually easier and less time consuming (especially when work orders are computerized). Because every work order respond, in principle, to an abnormal occurrence, events related to each single component could be easily compiled. The quality of information found in the work orders is generally not very good, because work order forms are filled by the personnel actually performing the work. Cases such as work orders open for months or years and work done on one component identified as being done on another are common. Logbooks, especially those filled by control room personnel, are
more accurate, but deriving raw data from them is extremely time consuming.

Even if the raw data are drawn from the logbook or maintenance records, it is still not certain whether all the failures of a certain component have been reported. If both sources are searched, the probability of failures not being reported is lower. However, it is still possible and it can result in an overestimate of component reliability.

It is understandable that the quality of component failure data is directly related to the quality of the plant records. If the plant has a dedicated collection system for reliability data in place, this would obviously be the best possible source of raw data.

The problem is even worse for demand related failures, when the actual number of demands is not readily available and has to be assessed on the basis of average time on power or calendar time. If a component is started for testing purpose, it is usually not known whether it started immediately or after a number of trials.

Operating experience for running (operational) failures involving standby systems is usually limited to a running time of about 1 hour (usual test running time). However it is often used (in analysis) as the long term failure rate, without any evidence that the long term failure rate is equal or comparable to the calculated short term rate.
Appendix 1
DATA SOURCES FOR THE IAEA DATA BASE

This Appendix provides an alphabetic listing of sources which were used in the compilation of the IAEA Data Base. The full name of the source is identified with a character which is part of the code. This character appears on the 5th position in the code of each record.

<table>
<thead>
<tr>
<th>SOURCE NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. HWR assessment</td>
</tr>
<tr>
<td>3. German Risk Study (Deutsche Risikostudie Kernkraftwerke), GRS, FRG, 1979.</td>
</tr>
</tbody>
</table>


16. Old PWR reactor


19. RKS 85-25 Reliability Data Book for Components in Swedish Nuclear Power Plants, RKS, SKI Sweden

Appendix 2

GENERIC FAILURE MODE DEFINITION AND CODES

A set of generic failure modes was developed to cover practically every failure which is accounted for in PSAs. Appendix 2 provides detail of the definition process, specific definitions of each of the major generic failure modes and the coding of generic failure modes.

1. Definition process

During the process of developing the generic failure modes the following was considered:

-The development of failure modes was to a great extent oriented towards component operation.

-During the definition process two distinctive models were considered:
  -demand related failure rates (failure probabilities) and
  -time related failure rates (subdivided in operating and standby related)

-Three effects of failures were considered in the definition process:
  -loss of function of the component
  -change of state without the command
  -failure to change state with command

-Another topic which to a certain extent influenced the determination of generic failure modes are the requirement of the system analyst on how to model (define) a particular event in fault trees.

-Finally, all the failure modes which are found in the various sources were considered to determine the final list of failure modes.

Altogether 26 failure modes were defined. 18 of them are considered to be of major importance, while the rest are only single component related (e.g. 'overheated' is pertinent to the electric heaters only), or very unique like control rod 'fail to insert'. These failure modes are self explanatory, so a detailed definition process was not necessary for them.

Major failure modes were described and defined and general use for each of them was suggested. To enable the data base user to follow the logic of placing particular failure mode under one of the generic categories, information on major failure modes is included below.

List of failure modes and associated codes is provided at the end of the Appendix.
2. Definitions of major failure modes

1. ALL MODES

Characterizes ANY failure which could possibly occur on certain components. Integrates: critical, degraded and incipient failures but their respective contribution to the total is not always known.

It is used in cases where detailed failure mode definition or data for particular failure mode is not available. It indicate that the component is or should be taken out of service under normal operation conditions.

2. DEGRADED

Failure which causes the component not to perform its function in the expected manner, or expected (designed) capacity but, which is not a catastrophic failure.

Usually pertinent to I & C components.

Time related, operation or standby

3. FAILURE TO CHANGE POSITION

Characterizes failure of components to move to a new required position.

Usually pertains to components which perform its function by changing (moving) between two discrete states (valves, breakers) (or change state discretely between two end points - regulating).

Applicable to components which perform its function by moving from one state to the other but limited to the situations where the required final state is irrelevant or characterized by other means, or not defined.

Demand related failure.
Failure to change state with command.

4. FAILURE TO REMAIN IN POSITION

Characterizes failure of components to remain in the required position.
Usually pertinent to components which perform its function by changing state between two discrete states (valves, breakers), or charge state regulating between two end points.

Used for two-state components which are required to remain in position during a mission time. Failure would cause move to opposite positions. Required position is irrelevant, characterized by other means or not defined at all.

Time related, operational or standby. Change of state without command.

5. FAIL TO CLOSE

Characterizes failure of a component to move to a new, closed position.

Subset of failure mode FAIL TO CHANGE POSITION.

Used for components which perform their function by moving from one state to another, but its closing is necessary to complete the mission.

Demand related failure. Failure to change state with command.

6. FAIL TO OPEN

Characterizes the failure of a component to move to a new, open position.

Subset of failure mode FAIL TO CHANGE POSITION. Opposite from FAIL TO CLOSE

Used for components which perform their function by moving from one state to another, when opening is necessary to complete mission.

Demand related failure. Failure to change state with command.

7. FAIL TO FUNCTION

One of the general failure modes, applicable mainly to components which do not move (macroscopically) to perform their function, (battery transformer, I & C equipment) or which have a complex function such as air-cooler, M-G sets etc. FAIL TO RUN does not adequately characterizes the component failure mode in these cases.
Characterizes the failure of components to function in required manner either continuously or when demanded.

Used for components which perform their function without movement on a macroscopic level, and for components which are characterized by providing output given an input or a command (continuously in time).

This failure mode is also applicable (and being used) as a composite failure mode for a pump not able to perform its function (pump fail to start, run, ruptured during operation or fail to accomplish the mission for any other reason).

Time related - operational.
Demand related
Loss of function of the component.

8. SHORT TO GROUND

Characterizes ground connections of any component where electric current is isolated on a higher-than-ground voltage.

Applicable to the electrical or I & C components which in any way conduct, transfer or modify electric current. Subset of failure mode SHORT CIRCUIT.

Used for components which are unable to perform their function or can cause disturbance to other equipment when isolation to ground is broken and a power to ground circuit is formed.

Time related failure operation or standby.
Loss of function of component.

9. SHORT CIRCUIT

Characterizes connections between two or more conductors (or conducting materials) which are normally isolated (insulated).

Applicable to practically all electrical and I & C components.

Used for components which are unable to perform their function, or cause disturbance to other equipment when insulation between two normally separated conductors disappear and a short circuit is formed.

Time related failure, operation or standby.
Loss of function of the component.
10. OPEN CIRCUIT

Characterizes disconnection (isolation) an electric circuit.

Applicable to practically all electrical and I & C components.

Used for components which are disabled to perform their function when electric conductor becomes internally isolated (insulated).

Time related failure, operation or standby.
Loss of function of component.

11. PLUG/RUPTURE

Unique failure mode applicable to piping.

Characterizes plugging or rupture of a pipe segment in manner that the required flow through that segment cannot be established or maintained.

Applicable to all kinds of pipes (but in IAEA data base used only for piping from source 'WASH-1400').

Time related failure, operation or standby.
Loss of function of the component.

12. PLUG

Characterizes any means of preventing flow in a required direction not caused by normal operation of component.

Applicable to most of the components through which flow of liquid/steam/gas flow is established or maintained. It is of particular interest to components whose internal parts can become loose and prevent normal flow (valves) or depositions can reduce flow below required level (filter/strainers).

Characterize any means of preventing flow in required direction not caused by normal operation of component.

Time related failure, operation or standby.
Loss of function of component.
Change of state without command.
13. SPURIOUS FUNCTION

Characterizes failure of components to retain their current status, e.g. to change state without being called to.

Complement to FAIL TO REMAIN IN POSITION, and applicable to components which perform their function by other means and not by changing state between two distinctive states.

Used for components which perform their function by being in a certain (usually dormant) state, but failure will cause changing state (operation of component).

Time related failure, standby or operation
Change of state without command.

14. FAIL TO RUN

Characterizes failure of a component to continue operation (usually rotating movement) during the required mission time.

Applicable to all components which perform their function by continuous movement.

Time related failure, operational.
Loss of function.

15. FAIL TO START

Characterizes the failure of components to start when demanded.

Applicable to all components which perform their function by starting and subsequently continuously moving (rotating).

Demand related failure.
Loss of function of component.

16. OTHER CRITICAL FAULTS

Characterizes the failures that would cause the component to FAIL TO FUNCTION if demanded before repair.

Uniquely defined failure mode, taken from Swedish Reliability Data Book.
Applicable to sensors representing sensor failures discovered prior to an actual demand.

Time related failure, standby.
Loss of function.

17. LEAKAGE/EXTERNAL LEAK

Characterizes a failure of component boundary to remain intact (to retain liquid). If the component performs another function, (e.g. pump) this failure will not necessarily prevent that other function.

Applicable to all components which retain liquid by any means. Not necessarily a catastrophic component failure. This failure mode sometimes overlap with failure mode RUPTURE. It was not possible to strictly separate this two failure modes in all cases.

In the IAEA data base its used almost entirely in cases of external leak.

Time related failure, standby or operation.
Loss of function of component (partial).

18. RUPTURE

Characterizes a large breach in liquid retaining boundary.

Applicable to all components which retain liquid by any means. It is always a catastrophic component failure. If the component performs some other function, not only to retain liquid (pump), this failure will completely prevent the component from functioning.

Used in the IAEA Data Base in cases where the original failure mode was rupture. Sometimes rupture also refers to component internal (e.g. valve), and there is a possibility of overlapping between this failure mode and failure mode INTERNAL LEAK.

Time related failure, operational or standby.
Loss of function of component
3. Failure modes and associated codes

Generic failure modes and respective codes

<table>
<thead>
<tr>
<th>FAILURE MODE</th>
<th>FAILURE MODE CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL MODES</td>
<td>A</td>
</tr>
<tr>
<td>DEGRADED</td>
<td>B</td>
</tr>
<tr>
<td>FAIL TO CHANGE POSITION</td>
<td>C</td>
</tr>
<tr>
<td>FAIL TO REMAIN IN POSITION</td>
<td>D</td>
</tr>
<tr>
<td>FAIL TO CLOSE</td>
<td>E</td>
</tr>
<tr>
<td>FAIL TO FUNCTION</td>
<td>F</td>
</tr>
<tr>
<td>SHORT TO GROUND</td>
<td>G</td>
</tr>
<tr>
<td>SHORT CIRCUIT</td>
<td>H</td>
</tr>
<tr>
<td>OPEN CIRCUIT</td>
<td>I</td>
</tr>
<tr>
<td>PLUG/RUPTURE</td>
<td>J</td>
</tr>
<tr>
<td>SPURIOUS FUNCTION</td>
<td>K</td>
</tr>
<tr>
<td>FAIL TO OPEN</td>
<td>O</td>
</tr>
<tr>
<td>PLUG</td>
<td>Q</td>
</tr>
<tr>
<td>FAIL TO RUN</td>
<td>R</td>
</tr>
<tr>
<td>FAIL TO START</td>
<td>S</td>
</tr>
<tr>
<td>RUPTURE</td>
<td>T</td>
</tr>
<tr>
<td>OTHER CRITICAL FAULTS</td>
<td>X</td>
</tr>
<tr>
<td>LEAKAGE/EXTERNAL LEAK</td>
<td>Y</td>
</tr>
<tr>
<td>DROPPED/UNCOPLED/OVERTRAVELED ROD</td>
<td>1</td>
</tr>
<tr>
<td>FAIL TO INSERT</td>
<td>2</td>
</tr>
<tr>
<td>IMPROPER MOVEMENT</td>
<td>3</td>
</tr>
<tr>
<td>CONTROL ROD FAILURE</td>
<td>4</td>
</tr>
<tr>
<td>OVERHEATED</td>
<td>5</td>
</tr>
<tr>
<td>LEAKAGE (SHELL)</td>
<td>6</td>
</tr>
<tr>
<td>LEAKAGE (TUBE)</td>
<td>7</td>
</tr>
<tr>
<td>INTERNAL LEAK</td>
<td>8</td>
</tr>
</tbody>
</table>

Generic failure modes as proposed in the IAEA Generic Data Base are one of a number of possible ways of defining them. It is, therefore, not unique and it would be indeed possible to define them in other ways.
Appendix 3

COMPONENT GROUPS IN THE IAEA DATA BASE

This Appendix provides a listing of component groups and associated codes. The main listing include all component groups found in the IAEA Data Base. There are also separate listing for mechanical, electrical, instrumentation and control and emergency power sources categories.
RELIABILITY DATA BASE
Listing of components groups and codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>QA</td>
<td>air cooler</td>
</tr>
<tr>
<td>UN</td>
<td>annunciator</td>
</tr>
<tr>
<td>BT</td>
<td>battery</td>
</tr>
<tr>
<td>BC</td>
<td>battery charger</td>
</tr>
<tr>
<td>QB</td>
<td>blower fan</td>
</tr>
<tr>
<td>CB</td>
<td>bus</td>
</tr>
<tr>
<td>CC</td>
<td>cable</td>
</tr>
<tr>
<td>KA</td>
<td>circuit breaker</td>
</tr>
<tr>
<td>KG</td>
<td>circuit breaker generator</td>
</tr>
<tr>
<td>KC</td>
<td>circuit breaker molded type</td>
</tr>
<tr>
<td>JE</td>
<td>clutch</td>
</tr>
<tr>
<td>QC</td>
<td>compressor</td>
</tr>
<tr>
<td>NK</td>
<td>computational module</td>
</tr>
<tr>
<td>OC</td>
<td>control rod</td>
</tr>
<tr>
<td>OD</td>
<td>control rod and drive mechanism</td>
</tr>
<tr>
<td>OR</td>
<td>control rod drive</td>
</tr>
<tr>
<td>UC</td>
<td>controller</td>
</tr>
<tr>
<td>EC</td>
<td>converter</td>
</tr>
<tr>
<td>QD</td>
<td>damper</td>
</tr>
<tr>
<td>DE</td>
<td>diesel engine</td>
</tr>
<tr>
<td>DG</td>
<td>diesel generator emergency AC</td>
</tr>
<tr>
<td>QF</td>
<td>fan cooler containment</td>
</tr>
<tr>
<td>KS</td>
<td>feeder(ABZ1E5G)</td>
</tr>
<tr>
<td>YF</td>
<td>filter</td>
</tr>
<tr>
<td>KT</td>
<td>fuse</td>
</tr>
<tr>
<td>DT</td>
<td>gas turbine driven generator emergency AC</td>
</tr>
<tr>
<td>FY</td>
<td>gasket</td>
</tr>
<tr>
<td>EG</td>
<td>generator</td>
</tr>
<tr>
<td>HK</td>
<td>heat exchanger</td>
</tr>
<tr>
<td>JH</td>
<td>heater</td>
</tr>
<tr>
<td>EH</td>
<td>heater electric</td>
</tr>
<tr>
<td>QV</td>
<td>hvac unit annulus ventilation</td>
</tr>
<tr>
<td>UI</td>
<td>indicating instrument</td>
</tr>
<tr>
<td>IA</td>
<td>instrumentation</td>
</tr>
<tr>
<td>IC</td>
<td>instrumentation channel analog</td>
</tr>
<tr>
<td>ID</td>
<td>instrumentation channel digital</td>
</tr>
<tr>
<td>YT</td>
<td>intake screen</td>
</tr>
<tr>
<td>EI</td>
<td>inverter</td>
</tr>
<tr>
<td>JL</td>
<td>lube oil cooler</td>
</tr>
<tr>
<td>UM</td>
<td>manual control device</td>
</tr>
<tr>
<td>MA</td>
<td>motor</td>
</tr>
<tr>
<td>MS</td>
<td>motor servo</td>
</tr>
<tr>
<td>MG</td>
<td>motor generator</td>
</tr>
<tr>
<td>FX</td>
<td>orifice</td>
</tr>
<tr>
<td>EB</td>
<td>panelboard</td>
</tr>
<tr>
<td>JP</td>
<td>penetration</td>
</tr>
<tr>
<td>FE</td>
<td>piping expansion joint</td>
</tr>
<tr>
<td>FN</td>
<td>piping nozzle</td>
</tr>
<tr>
<td>FR</td>
<td>piping rupture diaphragm</td>
</tr>
<tr>
<td>FS</td>
<td>piping straight section</td>
</tr>
<tr>
<td>FT</td>
<td>piping tees</td>
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<tr>
<td>FW</td>
<td>piping welds</td>
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<tr>
<td>EP</td>
<td>power supply</td>
</tr>
<tr>
<td>PD</td>
<td>pump diesel driven</td>
</tr>
<tr>
<td>PM</td>
<td>pump motor driven</td>
</tr>
<tr>
<td>PT</td>
<td>pump turbine driven</td>
</tr>
<tr>
<td>PW</td>
<td>pump without driver</td>
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<td>SI</td>
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<td>TT</td>
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</tr>
<tr>
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</tr>
<tr>
<td>TV</td>
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</tr>
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<td>transformer station service including excitation</td>
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<td>TX</td>
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### Mechanical components groups and codes

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<th>Code</th>
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</tr>
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<td>OR</td>
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<td>control rod</td>
<td>QF</td>
<td>damper</td>
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<td>damper</td>
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<tr>
<td>OR</td>
<td>control rod drive</td>
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<td>JP</td>
<td>lube oil cooler</td>
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<tr>
<td>VA</td>
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<td>EC</td>
<td>converter</td>
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<tr>
<td>KS</td>
<td>feeder(ABZWEIG)</td>
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<td>KT</td>
<td>fuse</td>
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<tr>
<td>EG</td>
<td>generator</td>
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<td>transformer main power generator or unit</td>
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<td>TE</td>
<td>transformer station service including excitation</td>
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### Instrumentation and control equipment groups and codes

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<td>controller</td>
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<td>AC</td>
<td>sensor core flux</td>
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<td>AF</td>
<td>sensor flow</td>
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<td>AL</td>
<td>sensor level</td>
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<tr>
<td>AP</td>
<td>sensor pressure</td>
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<tr>
<td>AT</td>
<td>sensor temperature</td>
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<tr>
<td>NS</td>
<td>signal conditioning system</td>
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<tr>
<td>NM</td>
<td>signal modifier</td>
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### Emergency power sources groups and codes

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<td>DT</td>
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Appendix 4

COMPONENT TYPES IN THE IAEA DATE BASE

This Appendix provides a listing of all component types and the associated three character code found in the IAEA Data Base. As in the Appendix 3, a main list and separate listings of mechanical, electrical, instrumentation and control and emergency power sources categories is given.
### RELIABILITY DATA BASE

#### Listing of components types and codes

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<thead>
<tr>
<th>Code</th>
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<td>battery</td>
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<td>BC1</td>
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<td>battery charger solid state</td>
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<td>bus 120 V DC</td>
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<td>bus 120 V AC , 220 V AC</td>
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<td>CB7</td>
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<td>OCR</td>
<td>control rod single control rod assembly</td>
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<td>OBS</td>
<td>control rod and drive mechanism BWR-s</td>
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<td>ODE</td>
<td>control rod and drive mechanism PWR-s</td>
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<td>ORA</td>
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<td>ORL</td>
<td>control rod drive lead screw roller nut drive mechanism</td>
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<td>ORM</td>
<td>control rod drive BWR application mechanical insertion function</td>
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<td>ORO</td>
<td>control rod drive BWR application hydraulic scram function</td>
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<td>UCA</td>
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<tr>
<td>UCE</td>
<td>controller electronic</td>
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<tr>
<td>UC1</td>
<td>controller pneumatic</td>
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<td>ECE</td>
<td>cascade E/S</td>
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<td>EES</td>
<td>converter square root</td>
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</tr>
<tr>
<td>QMA</td>
<td>damper</td>
<td></td>
</tr>
<tr>
<td>QDA</td>
<td>damper Automatic backdraft, parallel blade</td>
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</tr>
<tr>
<td>QDO</td>
<td>damper Modulating, opposed blade, 2X48 inches</td>
<td></td>
</tr>
<tr>
<td>QDT</td>
<td>damper shut off, two position parallel blade</td>
<td></td>
</tr>
<tr>
<td>QDC</td>
<td>damper containment fan coolers system</td>
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</table>
QDM damper manual (HVAC)
DEA diesel engine
DEI diesel engine No.2 fuel oil, 4 stroke, in-line
DEV diesel engine No.2 fuel oil, 4 stroke, V block
DGA diesel generator emergency AC
DG4 diesel generator emergency AC 4160 V AC
QFV fan containment ventilation fan
QFC fan cooler containment
QFH fan cooler reactor building cooling units
KSF feeder(ABZWEIG)
YFM filter liquid, mechanical restriction
UCF flow controller
KTA fuse all voltage levels
DTG gas turbine driven generator emergency AC
FYA gasket
EGS generator AC steam turbine driven
EGD generator DC
HXA heat exchanger
HXR heat exchanger residual heat removal HX
HXS heat exchanger secondary component cooling HX
HXX heat exchanger U tube horizontal shell and tube
HXXD heat exchanger U tube shell and tube plus steam drum
HXXV heat exchanger U tube vertical shell and tube
HXC heat exchanger helical coil
HXB heat exchanger straight tube horizontal shell and tube
HXXZ heat exchanger straight tube radiator type
HXXM heat exchanger straight tube vertical shell and tube
EHT heat tracing pipe heater
ENA heater air heater
JHF heater feedwater
EHP heater pressurizer heater
QVA hvac unit annulus ventilation
QVX hvac unit auxiliary building
QVB hvac unit battery room ventilation
QVC hvac unit cable spreading room
QVR hvac unit control room ventilation
QVE hvac unit electric equipment area ventilation
QVI hvac unit intermediate building
UIE indicating instrument electronic
IAA instrumentation
ICC instrumentation channel analog core flux
ICF instrumentation channel analog flow
ICL instrumentation channel analog level
ICP instrumentation channel analog pressure
ICT instrumentation channel analog temperature
IDL instrumentation channel digital level
IDP instrumentation channel digital pressure
YTS intake screen service water system
EIA inverter
EII inverter instrument
EIS inverter solid state 120 volts AC
EIZ inverter static single phase
EIY inverter static three phase
UEY isolating diode assembly
JLC tube oil cooler
UMC manual control device pushbutton
MAA motor
MPH motor HP emergency coolant injection pump motor
MPL motor LP emergency coolant injection pump motor
MPS motor LP service water pump motor
MPF motor auxiliary boiler feed pump motor
MPC motor circulating water pump motor
MPE motor condensate extraction pump motor
MPZ motor emergency service water pump motor
MPX motor end shield tank cooling pump motor
MPB motor generator main lube oil pump motor
MPM motor main moderator pump motor
MPQ motor powerhouse upper level service water pump motor
MPP motor primary heat transport feed circuit pump motor
MPV motor primary heat transport pump motor
MPW motor shutdown cooling water pump motor
MAC motor AC
MAI motor AC induction
MAS motor AC split phase
MAW motor AC synchronous single phase
MPK motor boiler feed pump
MSS motor servo
MGX motor generator
MGA motor generator AC 220 V
MGD motor generator D-C
MGR motor generator D-C rotating converter
FXA orifice
FXT  orifice, test valve, flow meter
EB1  panelboard 120 V AC
JPE  penetration electrical
JPP  penetration piping
FSS  pipe (nuclear grade) straight section diameter size less than 1 inch
FS3  piping <= 3" diameter
FSM  piping > 3" diameter
FE5  piping elbow 4-6 inches
FEA  piping expansion joint
FE3  piping expansion joint 3" 400 PSI corrugated steel
FNA  piping nozzle
FNS  piping nozzle spray
FRL  piping rupture diaphragm 10-16 inches
FSA  piping straight section
FTA  piping tees
FTL  piping thermowell 6-10 inches
FWS  piping welds less than 4" connecting weld
EPA  power supply
PWW  pump
PHA  pump auxiliary boiler feed pump
PWC  pump centrifugal
PMD  pump centrifugal horizontal flow 22-820 l/s
PMB  pump centrifugal horizontal flow 22-820 l/s
PWE  pump centrifugal vertical flow 70-1900 l/s
PWF  pump condensate extraction pump
PWP  pump positive displacement
PDA  pump diesel driven
PDC  pump diesel driven containment spray pump
PMX  pump motor driven auxiliary feedwater pump
PMD  pump motor driven centrifugal horizontal flow rate 130-200 kg/s; head .7 MPa
PMO  pump motor driven centrifugal horizontal and vertical flow rate 30 kg/s; head 2.2-6.7 MPa
PMN  pump motor driven centrifugal horizontal and vertical flow rate 75-250 kg/s; head .3-.9 MPa
PMN  pump motor driven centrifugal horizontal flow rate: 40-60 kg/s; head .5-.7 MPa
PMP  pump motor driven centrifugal reactor coolant pump flow rate 1036-2347 kg/s; head .3-.4 MPa
PMW  pump motor driven centrifugal wet flow rate 75-150 kg/s; head 1.3-1.8 MPa
PMQ  pump motor driven centrifugal, horizontal and vertical flow rate 120-240 kg/s; head 1.2-1.8 MPa
PMH  pump motor driven charging/high pressure injection
PME  pump motor driven component cooling
PMC  pump motor driven containment spray
PMG  pump motor driven electrical equipment area ventilation cooling pump
<table>
<thead>
<tr>
<th>Pump Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHF</td>
<td>pump motor driven emergency feedwater pump</td>
</tr>
<tr>
<td>PMV</td>
<td>pump motor driven high pressure injection</td>
</tr>
<tr>
<td>PMI</td>
<td>pump motor driven high pressure (&gt;20 bar) applicable to HHSI, CVCS and auxiliary feedwater pumps</td>
</tr>
<tr>
<td>PMZ</td>
<td>pump motor driven include CCW, SW, RHR, boric acid transfer, boron injection recirc.</td>
</tr>
<tr>
<td>PMT</td>
<td>pump motor driven include containment spray, standby liquid control</td>
</tr>
<tr>
<td>PMJ</td>
<td>pump motor driven includes reactor coolant, reactor recirculating, CW, feedwater, cond.</td>
</tr>
<tr>
<td>PUL</td>
<td>pump motor driven low pressure &lt;20 bar applicable to ESWS, CCWS, LHSI/RHR, CSS, boric acid transfer pumps</td>
</tr>
<tr>
<td>PML</td>
<td>pump motor driven low pressure injection</td>
</tr>
<tr>
<td>PUM</td>
<td>pump motor driven main feed pumps</td>
</tr>
<tr>
<td>PUR</td>
<td>pump motor driven main steam relief hydraulic pump</td>
</tr>
<tr>
<td>PUE</td>
<td>pump motor driven primary component cooling water pump</td>
</tr>
<tr>
<td>PUB</td>
<td>pump motor driven primary service water booster pump</td>
</tr>
<tr>
<td>PUK</td>
<td>pump motor driven primary service water pump</td>
</tr>
<tr>
<td>PUP</td>
<td>pump motor driven reciprocating (positive displacement) flow rate 2.5-3.9 kg/s; head 8.7 MPa;</td>
</tr>
<tr>
<td>PUZ</td>
<td>pump motor driven recirculation pump</td>
</tr>
<tr>
<td>PUW</td>
<td>pump motor driven residual heat removal pump</td>
</tr>
<tr>
<td>PMS</td>
<td>pump motor driven safety injection pump</td>
</tr>
<tr>
<td>PUS</td>
<td>pump motor driven screw flow rate 550 kg/s; head 0.3 MPa</td>
</tr>
<tr>
<td>PUF</td>
<td>pump motor driven secondary component cooling water</td>
</tr>
<tr>
<td>PMK</td>
<td>pump motor driven secondary service water</td>
</tr>
<tr>
<td>PUC</td>
<td>pump motor driven service water pump used in charging pump cooling system</td>
</tr>
<tr>
<td>PUV</td>
<td>pump motor driven well water pump</td>
</tr>
<tr>
<td>PTA</td>
<td>pump turbine driven</td>
</tr>
<tr>
<td>PTF</td>
<td>pump turbine driven auxiliary feedwater</td>
</tr>
<tr>
<td>PTC</td>
<td>pump turbine driven centrifugal pump flow rate 240 kg/s; head 1.8 MPa</td>
</tr>
<tr>
<td>PTX</td>
<td>pump turbine driven emergency feedwater pump</td>
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<tr>
<td>PTS</td>
<td>pump turbine driven high pressure &gt; 20 bar include CVCS, emergency charging system, aux. feedwater pumps</td>
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<tr>
<td>ARB</td>
<td>radiation monitors BWR main steam line</td>
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<tr>
<td>URS</td>
<td>reactor scram system</td>
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<tr>
<td>ERE</td>
<td>rectifier excitation rectifier over 600 V</td>
</tr>
<tr>
<td>ERP</td>
<td>rectifier precipitator rectifier over 600 V</td>
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<tr>
<td>ERS</td>
<td>rectifier static</td>
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<tr>
<td>RNA</td>
<td>relay</td>
</tr>
<tr>
<td>RAA</td>
<td>relay auxiliary</td>
</tr>
<tr>
<td>RCL</td>
<td>relay control</td>
</tr>
<tr>
<td>RCA</td>
<td>relay control AC</td>
</tr>
<tr>
<td>RCD</td>
<td>relay control DC</td>
</tr>
<tr>
<td>RCE</td>
<td>relay control electromechanical</td>
</tr>
<tr>
<td>RPH</td>
<td>relay power 300-460 A</td>
</tr>
<tr>
<td>RPL</td>
<td>relay power 40-60 A</td>
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</tbody>
</table>
RRA  relay protective
RRO  relay protective overload protection
RRS  relay protective switchgear protection
RRV  relay protective voltage protection
RTA  relay time delay
RTB  relay time delay bimetallic
RTP  relay time delay pneumatic
RTS  relay time delay solid state
RYA  relay coil
RXA  relay contacts
ACA  sensor core flux
AFA  sensor flow
ALA  sensor level
ALR  sensor level reactor water level
APA  sensor pressure
APR  sensor pressure reactor and containment sensor
APD  sensor pressure difference
ATA  sensor temperature
NCA  signal comparator bistable
NSA  signal conditioning system for core flux, level, flow, pressure, temperature general
NMA  signal modifier
NMT  signal modifier current-current transducer
NMP  signal modifier current-pneumatic transducer
NMV  signal modifier current-voltage transducer
NMS  signal modifier square root extractor
NMO  signal modifier voltage-pneumatic transducer
UEH  solid state devices high power application
UEL  solid state devices low power application
ECM  static converter for reactor main coolant pumps
YSF  strainer water
YSF  strainer/filter
SDA  switch digital channel pressure/vacuum, pressure, level
SFA  switch flow
SLA  switch level
SIA  switch limit
SIE  switch limit electronic
SMA  switch manual
SPA  switch pressure
STA  switch temperature
SQA  switch torque
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Voltage/Configuration</th>
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<tbody>
<tr>
<td>SCC</td>
<td>switch contacts</td>
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<td>JTF</td>
<td>tank storage FWST</td>
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<td>JTR</td>
<td>tank storage RMST</td>
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<td>EBA</td>
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<tr>
<td>TAA</td>
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<tr>
<td>TA2</td>
<td>transformer 220/120 V</td>
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<td>TA5</td>
<td>transformer 50/6 kV</td>
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<td>TA6</td>
<td>transformer 6kV/380 V</td>
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<td>TA8</td>
<td>transformer 8 kV / 6 kV</td>
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<td>TAD</td>
<td>transformer dry 4 kV/600 V</td>
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<tr>
<td>TAE</td>
<td>transformer dry 600 V/208 V</td>
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<tr>
<td>TTS</td>
<td>transformer auto liquid filled, single phase</td>
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<tr>
<td>TTT</td>
<td>transformer auto liquid filled, three phase</td>
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<tr>
<td>TIP</td>
<td>transformer instrument potential</td>
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<tr>
<td>TIC</td>
<td>transformer instrument transformer current</td>
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<tr>
<td>TIC</td>
<td>transformer instrument transformer current</td>
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<td>TSA</td>
<td>transformer main power generator or unit liquid</td>
<td>single phase 146-242 kV</td>
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<td>TM4</td>
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<td>TS5</td>
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<td>TVR</td>
<td>transformer regulating 120 V AC</td>
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<td>TET</td>
<td>transformer station service including excitation</td>
<td>dry type, three phase</td>
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<td>TES</td>
<td>transformer station service including excitation</td>
<td>dry type, single phase all voltage</td>
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<td>TEG</td>
<td>transformer station service including excitation</td>
<td>liquid filled, single phase &lt;=40 kV</td>
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<td>TEH</td>
<td>transformer station service including excitation</td>
<td>liquid filled, three phase &lt;=40 kV</td>
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<td>transformer station start and auxiliary Voltage</td>
<td>levels: 130/6 kV, 70/6 kV, 20/6 kV</td>
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<td>phase</td>
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<td>TUT</td>
<td>transformer substation liquid filled, three</td>
<td>phase</td>
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<tr>
<td>LFF</td>
<td>transmitter flow</td>
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<td>LAD</td>
<td>transmitter flow, level, pressure</td>
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<td>LLL</td>
<td>transmitter level</td>
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<td>LTT</td>
<td>transmitter temperature</td>
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<tr>
<td>JUC</td>
<td>turbine combustion</td>
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<tr>
<td>JUP</td>
<td>turbine steam driven</td>
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<tr>
<td>JUS</td>
<td>turbine steam driven condensing, single stage,</td>
<td>500-999 HP</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
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<tr>
<td>JUN</td>
<td>turbine steam driven non condensing 1000-5000 HP</td>
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<tr>
<td>JUM</td>
<td>turbine steam driven non condensing, multi stage, less than 500 HP</td>
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<tr>
<td>JUH</td>
<td>turbine turbine/HPCI assembly</td>
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<tr>
<td>VWO</td>
<td>valve ADS depressurization valve</td>
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<tr>
<td>WA</td>
<td>valve angle valve</td>
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<tr>
<td>WB</td>
<td>valve ball valve</td>
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<tr>
<td>WT</td>
<td>valve butterfly valve</td>
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<tr>
<td>WD</td>
<td>valve condenser steam discharge valve</td>
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<tr>
<td>WP</td>
<td>valve diaphragm</td>
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<tr>
<td>WF</td>
<td>valve flow control 1/2 inch, air fixed flow</td>
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<tr>
<td>WG</td>
<td>valve gate</td>
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</tr>
<tr>
<td>WL</td>
<td>valve globe valve</td>
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<tr>
<td>WE</td>
<td>valve high pressure shifting valve (steam dump)</td>
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<td>WN</td>
<td>valve needle valve</td>
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<td>valve plug valve</td>
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<td>WX</td>
<td>valve pressure regulating</td>
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<td>WZ</td>
<td>valve pressure regulating 2-6 inches</td>
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<td>VRB</td>
<td>valve primary relief valve BWR</td>
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<td>valve relief</td>
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<td>VRM</td>
<td>valve relief main steam atmospheric relief valve</td>
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<tr>
<td>VR6</td>
<td>valve relief &amp; safety diameter between 2 and 6 inches</td>
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<tr>
<td>VR8</td>
<td>valve relief &amp; safety diameter larger than 6 inches</td>
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<td>VR2</td>
<td>valve relief &amp; safety diameter less than 2 inches</td>
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<tr>
<td>VSA</td>
<td>valve safety</td>
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<tr>
<td>VWV</td>
<td>valve vent 3/4 inch, float operated, tank vent</td>
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</tr>
<tr>
<td>VA1</td>
<td>valve air operated</td>
<td></td>
</tr>
<tr>
<td>VAR</td>
<td>valve air operated all systems except raw water return line</td>
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<tr>
<td>VAP</td>
<td>valve air operated purge isolation</td>
<td></td>
</tr>
<tr>
<td>VAQ</td>
<td>valve air operated raw water return line</td>
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<tr>
<td>VAZ</td>
<td>valve air operated turbine stop valve</td>
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<tr>
<td>VAI</td>
<td>valve air operated vent isolation</td>
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<tr>
<td>VAE</td>
<td>valve air operated PWR + BWR (ESF systems valves only)</td>
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<tr>
<td>VAT</td>
<td>valve air operated butterfly diameter larger than 24 inches</td>
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<td>VAB</td>
<td>valve air operated general (BWR application)</td>
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<td>VAW</td>
<td>valve air operated general (PWR application)</td>
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<tr>
<td>VAK</td>
<td>valve air operated globe diameter between 2 and 6 inches</td>
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<td>VAL</td>
<td>valve air operated globe diameter less than 2 inches</td>
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<tr>
<td>VWH</td>
<td>valve air operated turbine governor valve</td>
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<td>valve composite by design</td>
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<td>VEA</td>
<td>valve explosive operated</td>
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<tr>
<td>Code</td>
<td>Description</td>
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<tr>
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<tr>
<td>VHA</td>
<td>valve hydraulic operated</td>
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<td>VX/</td>
<td>valve manual</td>
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<tr>
<td>VX/E</td>
<td>valve manual PWR + BWR (ESF systems valves only)</td>
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<tr>
<td>VX/T</td>
<td>valve manual butterfly all systems except HVAC</td>
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<tr>
<td>VX/G</td>
<td>valve manual gate diameter between 12 and 24 inches</td>
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<td>VX/H</td>
<td>valve manual gate diameter between 2 and 6 inches</td>
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<td>VX/I</td>
<td>valve manual gate diameter between 6 and 12 inches</td>
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<td>VX/S</td>
<td>valve manual gate diameter less than 2 inches</td>
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<td>VMA</td>
<td>valve motor operated</td>
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<td>VMC</td>
<td>valve motor operated Chemical and volume control system valves</td>
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<td>valve motor operated butterfly diameter between 6 and 12 inches</td>
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<td>valve motor operated isolation valve pipe diameter &lt;=100 mm</td>
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<td>valve motor operated regulating valve</td>
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<td>valve pneumatic operated isolation hydraulic scram system valve, pipe diameter &lt;100 mm</td>
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<td>V/A</td>
<td>valve pneumatic operated isolation pipe dimension &lt;=100mm</td>
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<td>valve self operated check ECCS &amp; RHR systems</td>
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<td>VCF</td>
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<td>VCS</td>
<td>valve self operated check diameter between 2 and 6 inches</td>
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VCT  valve self operated check diameter between 6 and 12 inches
VCH  valve self operated check diameter larger than 24 inches
VCB  valve self operated check diameter less than 2 inches
VCM  valve self operated check main steam check valve
VCJ  valve self operated check pipe dimension > 100mm
VWI  valve self operated check pipe dimension 500mm, 600 mm (main steam system)
VCI  valve self operated check pipe dimension <=100 mm
VCW  valve self operated check swing
VCN  valve self operated check testable
VCZ  valve self operated check tilting disc
VSC  valve self operated code safety valve
VWK  valve self operated pilot valve
VSD  valve self operated pressurizer safety valve short inlet piping
VSB  valve self operated primary safety valve
VSM  valve self operated safety main steam
VSP  valve self operated safety valves PWR
VVA  valve self operated vacuum valve
VCU  valve self operated (motor operated) stop check
VSR  valve self operated (pilot operated) safety valve (pressure relief system) pipe dimensions 125,150,300 mm
VRR  valve self operated (pilot or power operated) pressurizer relief
VAM  valve self operated, motor operated (redundant closure) stop check pipe dimension 500mm, 600mm (main steam system valve)
VDA  valve solenoid operated
VDO  valve solenoid operated all systems, except HVAC
VDH  valve solenoid operated used in HVAC
CWA  wire
CWC  wire control circuit typical circuit, several joints
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<tr>
<th>Component</th>
<th>Description</th>
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<td>QBF</td>
<td>blower fan</td>
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<tr>
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<td>blower ventilator air circulating fan</td>
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<td>JEM</td>
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<td>JEE</td>
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<td>compressor MSIV air compressor</td>
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<td>compressor containment air control</td>
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<tr>
<td>QCI</td>
<td>compressor instrument air</td>
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<td>QCP</td>
<td>compressor pumpback (annulus ventilation)</td>
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<td>control rod clustered silver, indium, cadmium control rods</td>
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<td>control rod cruciform, boron carbide control rods</td>
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<td>control rod KMW PWR type</td>
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<td>control rod single control rod assembly</td>
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<td>control rod and drive mechanism BWR-s</td>
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<td>ORA</td>
<td>control rod drive</td>
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<td>ORL</td>
<td>control rod drive, lead screw roller nut drive mechanism</td>
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<td>control rod drive BWR application mechanical insertion function</td>
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<td>QDO</td>
<td>damper, Modulating, opposed blade, 36X48 inches</td>
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<tr>
<td>QDT</td>
<td>damper, shut off, two position parallel blade</td>
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<tr>
<td>QDC</td>
<td>damper, containment fan coolers system</td>
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<td>QDM</td>
<td>damper manual (HVAC)</td>
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<td>QFV</td>
<td>fan containment ventilation Yen</td>
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<td>QFC</td>
<td>fan cooler containment</td>
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<td>QFH</td>
<td>fan cooler reactor building cooling units</td>
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<td>YFM</td>
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<td>gasket</td>
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<td>HXA</td>
<td>heat exchanger</td>
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<td>HXR</td>
<td>heat exchanger residual heat removal</td>
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<tr>
<td>HXS</td>
<td>heat exchanger secondary component cooling</td>
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</tbody>
</table>

**Heat Exchangers**

- HXX: heat exchanger U tube horizontal shell and tube
- HXD: heat exchanger U tube shell and tube plus steam drum
- HXV: heat exchanger U tube vertical shell and tube
- HXC: heat exchanger helical coil
- HKB: heat exchanger straight tube horizontal shell and tube
- HXZ: heat exchanger straight tube radiator type
- HXM: heat exchanger straight tube vertical shell and tube
- JHF: heater feedwater
- QVA: hvac unit annulus ventilation
- QVX: hvac unit auxiliary building
- QVB: hvac unit battery room ventilation
- QVC: hvac unit cable spreading room
- QVR: hvac unit control room ventilation
- QVE: hvac unit electric equipment area ventilation
- QVI: hvac unit intermediate building
- YTS: intake screen service water system
- JLC: lube oil cooler
- FXA: orifice
- FXT: orifice, test valve, flow meter
- JPE: penetration electrical
- JPP: penetration piping
- FSS: pipe (nuclear grade) straight section diameter size less than 1 inch
- FS3: piping <= 3" diameter
- FSM: piping > 3" diameter
- FES: piping elbow 4-6 inches
- FEA: piping expansion joint
- FE3: piping expansion joint 3 = 400 PSI corrugated steel
- FNA: piping nozzle
- FNS: piping nozzle spray
- FRL: piping rupture diaphragm 10-16 inches
- FSA: piping straight section
- FTA: piping tees
- FTL: piping thermowell 6-10 inches
- FNS: piping welds less than 4" connecting weld
- PWZ: pump
- PVA: pump, auxiliary boiler feed pump
- PWC: pump centrifugal
- PWD: pump centrifugal horizontal flow 22-820 l/s
- PWB: pump centrifugal horizontal flow 22-820 l/s
- PWE: pump centrifugal vertical flow 70-1900 l/s
- PWF: pump condensate extraction pump
PWP pump positive displacement
PDA pump diesel driven
PDC pump diesel driven containment spray pump
PMA pump motor driven
PMX pump motor driven auxiliary feedwater pump
PMO pump motor driven centrifugal horizontal flow rate 130-200 kg/s; head .7 MPa
PMQ pump motor driven centrifugal horizontal and vertical flow rate 30 kg/s; head 2.2-6.7 MPa
PMH pump motor driven centrifugal horizontal and vertical flow rate 120-240 kg/s; head 1.2-1.8 MPa
PMK pump motor driven charging/high pressure injection
PMC pump motor driven containment spray
PMG pump motor driven electrical equipment area ventilation cooling pump
PMF pump motor driven emergency feedwater pump
PMV pump motor driven high pressure injection
PMI pump motor driven high pressure (> 20 bar) applicable to HHSI, CVCS and auxiliary feedwater pumps
PMJ pump motor driven includes reactor coolant, reactor recirculating, CW feedwater, cond.
PUL pump motor driven low pressure <20 bar applicable to ESWS, CCWS, LHSI/RHR, CSS, boric acid transfer pumps
PML pump motor driven low pressure injection
PUM pump motor driven main feed pumps
PUR pump motor driven main steam release hydraulic pump
PEE pump motor driven primary component cooling water pump
PUB pump motor driven primary service water booster pump
PUK pump motor driven primary service water pump
PUP pump motor driven reciprocating (positive displacement) flow rate 2.5-3.9 kg/s; head 8.7 MPa
PUZ pump motor driven recirculation pump
PUW pump motor driven residual heat removal pump
PMS pump motor driven safety injection pump
PUS pump motor driven screw flow rate 550 kg/s; head 0.3 MPa
PUF pump motor driven secondary component cooling water
PKM pump motor driven secondary service water
PUC pump motor driven service water pump used in charging pump cooling system
PUV pump motor driven well water pump
PTA pump turbine driven
PTF pump turbine driven auxiliary feedwater
PTC pump turbine driven centrifugal pump flow rate 240 kg/s; head 1.8 MPa
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tr>
<td>PTX</td>
<td>pump turbine driven emergency feedwater pump</td>
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<td>PTS</td>
<td>pump turbine driven high pressure &gt; 20 bar include CVCS, emergency charging system, aux. feedwater pumps</td>
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<td>YSD</td>
<td>strainer service water (charging pump cooling system) duplex</td>
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<td>TSF</td>
<td>strainer/ filter</td>
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<td>JTF</td>
<td>tank storage FWST</td>
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<tr>
<td>JTR</td>
<td>tank storage RWST</td>
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<td>JUC</td>
<td>turbine combustion</td>
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<td>JUP</td>
<td>turbine steam driven</td>
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<td>JUS</td>
<td>turbine steam driven condensing, single stage, 500-999 HP</td>
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<td>JUN</td>
<td>turbine steam driven non condensing 1000-5000 HP</td>
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<td>JUM</td>
<td>turbine steam driven non condensing, multi stage, less than 500 HP</td>
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<td>valve flow control 1/2 inch, air fixed flow</td>
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<td>VAL</td>
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<td>valve relief &amp; safety diameter larger than 6 inches</td>
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<td>VAQ</td>
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<td>VAZ</td>
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<td>WVAH</td>
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</tr>
<tr>
<td>VSM</td>
<td>valve self operated safety main steam</td>
</tr>
<tr>
<td>VSP</td>
<td>valve self operated safety valves PWR</td>
</tr>
<tr>
<td>VYA</td>
<td>valve self operated vacuum valve</td>
</tr>
<tr>
<td>VCU</td>
<td>valve self operated (motor operated) stop check</td>
</tr>
<tr>
<td>VSR</td>
<td>valve self operated (pilot operated) safety valve (pressure relief system) pipe dimensions 125, 150, 300 mm</td>
</tr>
<tr>
<td>VRR</td>
<td>valve self operated (pilot or power operated) pressurizer relief</td>
</tr>
<tr>
<td>VMM</td>
<td>valve self operated, motor operated (redundant closure) stop check pipe dimension 500 mm, 600 mm (main steam system valve)</td>
</tr>
<tr>
<td>VDA</td>
<td>valve solenoid operated</td>
</tr>
<tr>
<td>VDO</td>
<td>valve solenoid operated all systems, except HVAC</td>
</tr>
<tr>
<td>VDH</td>
<td>valve solenoid operated used in HVAC</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>BTA</td>
<td>battery</td>
</tr>
<tr>
<td>BTB</td>
<td>battery 125 V</td>
</tr>
<tr>
<td>BTL</td>
<td>battery lead acid</td>
</tr>
<tr>
<td>BEN</td>
<td>battery nickel cadmium</td>
</tr>
<tr>
<td>BET</td>
<td>battery (power system) wet cell</td>
</tr>
<tr>
<td>BCA</td>
<td>battery charger</td>
</tr>
<tr>
<td>BC1</td>
<td>battery charger 120 V</td>
</tr>
<tr>
<td>BCR</td>
<td>battery charger rectifier</td>
</tr>
<tr>
<td>BCS</td>
<td>battery charger solid state</td>
</tr>
<tr>
<td>CBA</td>
<td>bus</td>
</tr>
<tr>
<td>CB5</td>
<td>bus &lt;= 500V</td>
</tr>
<tr>
<td>CB2</td>
<td>bus 120 V AC , 220 V AC</td>
</tr>
<tr>
<td>CB1</td>
<td>bus 120 V DC</td>
</tr>
<tr>
<td>CB3</td>
<td>bus 380 V</td>
</tr>
<tr>
<td>CB6</td>
<td>bus 6 kV</td>
</tr>
<tr>
<td>CB0</td>
<td>bus DC</td>
</tr>
<tr>
<td>CB8</td>
<td>bus bare outdoor switchgear</td>
</tr>
<tr>
<td>CBH</td>
<td>bus high voltage, indoor voltage &gt;= 4 kV</td>
</tr>
<tr>
<td>CB1</td>
<td>bus insulated switchgear bus 601-15 kV</td>
</tr>
<tr>
<td>CBL</td>
<td>bus low voltage indoor voltage &lt;= 600 V</td>
</tr>
<tr>
<td>CBM</td>
<td>bus metal enclosures</td>
</tr>
<tr>
<td>CCC</td>
<td>cable control copper conductors</td>
</tr>
<tr>
<td>CCP</td>
<td>cable power</td>
</tr>
<tr>
<td>CCS</td>
<td>cable signal (supervisory)</td>
</tr>
<tr>
<td>KAA</td>
<td>circuit breaker</td>
</tr>
<tr>
<td>KAC</td>
<td>circuit breaker 4.16 kV</td>
</tr>
<tr>
<td>KAL</td>
<td>circuit breaker 6 kV</td>
</tr>
<tr>
<td>KAL</td>
<td>circuit breaker 600 V</td>
</tr>
<tr>
<td>KAM</td>
<td>circuit breaker Voltage between 6 and 10 kV</td>
</tr>
<tr>
<td>KDC</td>
<td>circuit breaker DC</td>
</tr>
<tr>
<td>KBF</td>
<td>circuit breaker bus feed breaker AC</td>
</tr>
<tr>
<td>KFT</td>
<td>circuit breaker fixed type including molden case</td>
</tr>
<tr>
<td>KGB</td>
<td>circuit breaker generator Manufactured by BBC</td>
</tr>
<tr>
<td>KAH</td>
<td>circuit breaker high power (leistungschalter)</td>
</tr>
<tr>
<td>KIA</td>
<td>circuit breaker indoor AC application</td>
</tr>
<tr>
<td>KID</td>
<td>circuit breaker indoor DC application</td>
</tr>
<tr>
<td>KIS</td>
<td>circuit breaker isolation</td>
</tr>
<tr>
<td>KMT</td>
<td>circuit breaker metal clad</td>
</tr>
<tr>
<td>KCT</td>
<td>circuit breaker molded type</td>
</tr>
<tr>
<td>KMS</td>
<td>circuit breaker motor operated 380 V</td>
</tr>
<tr>
<td>KDA</td>
<td>circuit breaker outdoor AC application</td>
</tr>
<tr>
<td>KRP</td>
<td>circuit breaker reactor protection</td>
</tr>
<tr>
<td>ECE</td>
<td>converter E/S</td>
</tr>
<tr>
<td>ECS</td>
<td>converter square root</td>
</tr>
<tr>
<td>KSF</td>
<td>feeder (ABZWEIG)</td>
</tr>
<tr>
<td>KTA</td>
<td>fuse all voltage levels</td>
</tr>
<tr>
<td>EGS</td>
<td>generator AC steam turbine driven</td>
</tr>
<tr>
<td>EGD</td>
<td>generator DC</td>
</tr>
<tr>
<td>EHT</td>
<td>heat tracing pipe heater</td>
</tr>
<tr>
<td>EHA</td>
<td>heater air heater</td>
</tr>
<tr>
<td>EHP</td>
<td>heater pressurizer heater</td>
</tr>
<tr>
<td>EIA</td>
<td>inverter</td>
</tr>
<tr>
<td>EII</td>
<td>inverter instrument</td>
</tr>
<tr>
<td>EIS</td>
<td>inverter solid state 120 volts AC</td>
</tr>
<tr>
<td>EIZ</td>
<td>inverter static single phase</td>
</tr>
<tr>
<td>EIX</td>
<td>inverter static three phase</td>
</tr>
<tr>
<td>MAA</td>
<td>motor</td>
</tr>
<tr>
<td>MPH</td>
<td>motor HP emergency coolant injection pump motor</td>
</tr>
<tr>
<td>MPL</td>
<td>motor LP emergency coolant injection pump motor</td>
</tr>
<tr>
<td>MPS</td>
<td>motor LP service water pump motor</td>
</tr>
<tr>
<td>MPF</td>
<td>motor auxiliary boiler feed pump motor</td>
</tr>
<tr>
<td>MPC</td>
<td>motor circulating water pump motor</td>
</tr>
<tr>
<td>MPE</td>
<td>motor condensate extraction pump motor</td>
</tr>
<tr>
<td>MPZ</td>
<td>motor emergency service water pump motor</td>
</tr>
<tr>
<td>MPX</td>
<td>motor end shield tank cooling pump motor</td>
</tr>
<tr>
<td>MPS</td>
<td>motor generator main lube oil pump motor</td>
</tr>
<tr>
<td>MPM</td>
<td>motor main moderator pump motor</td>
</tr>
<tr>
<td>MQP</td>
<td>motor powerhouse upper level service water pump</td>
</tr>
<tr>
<td>MPP</td>
<td>motor primary heat transport feed circuit motor</td>
</tr>
<tr>
<td>MPV</td>
<td>motor primary heat transport pump motor</td>
</tr>
<tr>
<td>MPW</td>
<td>motor shutdown cooling water pump motor</td>
</tr>
<tr>
<td>MAC</td>
<td>motor AC</td>
</tr>
<tr>
<td>MIA</td>
<td>motor AC induction</td>
</tr>
<tr>
<td>MAS</td>
<td>motor AC split phase</td>
</tr>
</tbody>
</table>
MAW  motor AC synchronous single phase
MPK  motor boiler feed pump
MSS  motor servo
MGX  motor generator
MGA  motor generator AC 220 V
MGO  motor generator D-C
MGR  motor generator D-C rotating converter
EB1  panelboard 120 V AC
EPA  power supply
ERE  rectifier excitation rectifier over 600 V
ERP  rectifier precipitator rectifier over 600 V
ERS  rectifier static
RWA  relay
RAA  relay auxiliary
RCL  relay control
RCA  relay control AC
RCD  relay control DC
RCE  relay control electromechanical
RPH  relay power 300-460 A
RPL  relay power 40-60 A
RRA  relay protective
RRD  relay protective overload protection
RRS  relay protective switchgear protection
RRT  relay protective voltage protection
RTA  relay time delay
RTB  relay time delay bimetallic
RTP  relay time delay pneumatic
RTS  relay time delay solid state
RYA  relay coil
RXA  relay contacts
ECM  static converter for reactor main coolant pumps
EBA  terminal board
TAA  transformer
TA2  transformer 220/120 V
TA5  transformer 50/6 kV
TA6  transformer 6kV/380 V
TAB  transformer 8 kV / 6 kV
TAD  transformer dry 4 kV/600 V
TAE  transformer dry 600 V/208 V
TTS  transformer auto liquid filled, single phase
TTT  transformer auto liquid filled, three phase
TIP  transformer instrument potential
TIC  transformer instrument transformer current transformer
TSA  transformer main power generator or unit liquid filled, single phase
TS4  transformer main power generator or unit liquid filled, single phase 146-242 kV
TS2  transformer main power generator or unit liquid filled, single phase 2-30 kV
TMA  transformer main power generator or unit liquid filled, three phase
TM2  transformer main power generator or unit liquid filled, three phase 2-30 kV
TM5  transformer main power generator or unit liquid filled, three phase 347-550 kV
TM4  transformer main power generator or unit liquid filled, three phase 46-242 kV
TS5  transformer main power generator or unit transformer liquid filled, single phase 347-550 kV
TVR  transformer regulating 120 V AC
TET  transformer station service including excitation dry type, three phase
TES  transformer station service including excitation dry type,single phase all voltage levels
TEG  transformer station service including excitation liquid filled, single phase <=40 kV
TEH  transformer station service including excitation liquid filled, three phase <=40 kV
TXA  transformer station start and auxiliary Voltage levels: 130/6 kV, 70/6 kV, 20/6 kV
TUS  transformer substation liquid filled, single phase
TUT  transformer substation liquid filled, three phase
CWA  wire
CWC  wire control circuit typical circuit, several joints
RELIABILITY DATA BASE

Instrumentation and control equipment types and codes

****************************************************

UNA annunciator
UNS annunciator module solid state
NKA computational module
UCA controller
UCE controller electronic
UCP controller pneumatic
UCF flow controller
UIE indicating instrument electronic
UEY isolating diode assembly
UMC manual control device pushbutton
ARB radiation monitors BWR main steam line
URS reactor scram system
ACA sensor core flux
AFA sensor flow
ALA sensor level
ALR sensor level reactor water level
APA sensor pressure
APR sensor pressure reactor and containment sensor
APD sensor pressure difference
ATA sensor temperature
NCA signal comparator bistable
NSA signal conditioning system for core flux, level, flow, pressure, temperature general
NMA signal modifier
NMT signal modifier current-current transducer
NMP signal modifier current-pneumatic transducer
NMV signal modifier current-voltage transducer
NMS signal modifier square root extractor
NMO signal modifier voltage-pneumatic transducer
UEH solid state devices high power application
UEL solid state devices low power application
SDA switch digital channel pressure/vacuum, pressure, level
SFA switch flow
SLA switch level
SIA switch limit
SIE switch limit electronic
SMA switch manual
SPA switch pressure
STA switch temperature
SQA switch torque
SCE switch contacts
LFF transmitter flow
LAD transmitter flow, level, pressure
LLL transmitter level
LPP transmitter pressure
LXR transmitter pressure difference
LTI transmitter temperature

****************************************************

Emergency power sources types and codes

****************************************************

DEA diesel engine
DEI diesel engine No.2 fuel oil, 4 stroke, in-line
DEV diesel engine No.2 fuel oil, 4 stroke, V block
DGA diesel generator emergency AC
DG4 diesel generator emergency AC 4160 V AC
DTG gas turbine driven generator emergency AC
Appendix 5

COMPLETE LISTING OF THE IAEA DATA BASE

This Appendix provides complete listing of the IAEA Data Base. Records are listed in alphabetical order of component types.

Each record is listed in following format:

Record code | Component type
-------------|-----------------|
Comp.boundary; Generic FM; Op. mode; Op.environment

Failure rate: Mid point; High; Low; Repair time; Error factor

Source; Ultimate source; Original FM
Comments

If some of the entries in the record are either blank or indicated as not available (n/a), then they are deleted in the printout. For example, for 'UNSFE' (it is 'annunciator module solid state') only recommended value was available in the source. Since high and low bound, error factor and repair time are not available, single value with prefix 'rec' (abbreviation for recommended) is included in the printout.
QAAFB  air cooler
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 6.0E-6/hr max: 4.0E-5/hr min: 3.0E-6/hr
Source: NUREG 2815 (table C.1.) Ultimate source: experts judgment and IREP data
Comment:

QAAFI  air cooler
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 1.0E-5/hr ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: Not consensus data. ANO-1 IREP study plant specific

UNAFE  annunciator general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail to operate on demand
FAILURE RATE OR PROBABILITY rec : 7.8E-7/hr high: 1.5E-5/hr low: 3.0E-8/hr REPAIR TIME: .2 hours
Source: IEEE 500 (1984) pg.41 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of different kinds of annunciators and different sources including non-nuclear. Principal reference:IEEE 500 (1977)

UNAKE  annunciator general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: operates spurious or false response
FAILURE RATE OR PROBABILITY rec : 5.6E-7/hr high: 1.1E-5/hr low: 2.0E-8/hr REPAIR TIME: .2 hours
Source: IEEE 500 (1984) pg.41 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite value of different kinds of annunciators and different sources including non-nuclear. Principal reference: IEEE 500 (1977)

UNSFE  annunciator module solid state general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail to operate on demand
FAILURE RATE OR PROBABILITY rec : 1.1E-6/hr
Comment: Reference : NUREG 2232 (1980)
UNSKE
annunciator module solid state general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: operates spurious or false response
FAILURE RATE OR PROBABILITY  
rec  :  1.7E-6/hr
Comment: Reference : NUREG 2232 (1980)

BTABN
battery
Component boundary: battery,container,terminal connections incl.1st breaker connect.  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: inadequate output
FAILURE RATE OR PROBABILITY  
rec  :  3.2E-6/hr high: 7.5E-6/hr low: 4.9E-7/hr REPAIR TIME: 4-7 hours
Comment: Operating experience:total pop. 51.Operational time 1.564.315 hrs No.of failures 5.
Repair time is range of medians.

BTAFN
battery
Component boundary: battery,container,terminal connections incl.1st breaker connect.  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output
FAILURE RATE OR PROBABILITY  
rec  :  6.4E-7/hr high: 3.0E-6/hr low: 3.0E-8/hr REPAIR TIME: 4-7 hours
Repair times range of median

BTAFO
battery
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  
mean  :  8.2E-8/hr 95%: 2.5E-7/hr  5%: 8.0E-10/hr REPAIR TIME: 11.2 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500(1977)(pg104),rec=median; max=80% of distribution. Operating experience: 96.426 hours of operation, no failures.
Repair time is mean of updated component maintenance duration.

BTAFT
battery
Component boundary: battery only  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failed effective output
FAILURE RATE OR PROBABILITY  
mean  :  1.3E-2/d 95%: 6.8E-2/d REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.41  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Demand failure rate is based on refueling outage testing interval Operating experience: Total pop.129.No of demands 531.Number of failures 7.  a=0.0346; b=2.59
BTAFFZ battery
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 7.6E-8/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant specific experience
Comment: Prior:IEEE 500(1977)(pg.104) lead-acid batteries,stationary type failure mode "catastrophic". Operating experience:2.0E+5 hours, no failures.

BTVFH battery 125 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 5.2E-7/hr  95%: 1.7E-6/hr  5%: 5.0E-8/hr  REPAIR TIME: 5 hours
Source: Old PWR  Ultimate source: Generic data updated with plant operating experience
Comment: Generic mean 7.5E-7/hr. Operating experience 4.1E+5 hours of operation, no failures.

BTAJ battery general
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: all modes  Original failure mode: hardware failure
FAILURE RATE OR PROBABILITY mean : 4.0E-4/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1,tbl.VI11.1-2  Ultimate source: assessed from several nuclear data sources
Comment: There is no specific failure mode assigned for this component in the source ASEP used IREP Procedure Guide value of 1.0E-6/hr assessed monthly system test.

BTLFE battery lead acid
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic (no output given challenge)
FAILURE RATE OR PROBABILITY rec : 4.6E-6/cy  high: 7.2E-6/cy  low: 2.7E-6/cy
Source: IEEE 500 (1984) pg.85  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of several sources.

BTLFE battery lead acid
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic (no output given challenge)
FAILURE RATE OR PROBABILITY rec : 2.0E-8/hr  high: 3.0E-8/hr  low: 0.0E-0/hr
Source: IEEE 500 (1984) pg.85  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of several sources. Tot.failure rate of batteries is estimated to be 1.6E-6/oper.hr, but 99.6% of failures were discovered through testing, what gives 6E-9/hr emergency oper.
**BTNAE**  battery nickel cadmium  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: all modes  
Original failure mode: all modes  
FAILURE RATE OR PROBABILITY  
rec : 2.6E-7/hr  
high: 9.9E-6/hr  
low: 1.1E-7/hr  
Source: IEEE 500 (1984) pg.91  
Ultimate source: expert opinion aggregation and operating experience  
Comment: Failure rate is composite of IEEE 500 (1977) and NPRD-2. Catastrophic failure rate is negligible, so all modes FR is  
donated by degraded mode.

**BTWFB**  battery (power system) wet cell  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: failure to provide proper output  
FAILURE RATE OR PROBABILITY  
mean : 2.0E-6/hr  
max: 1.0E-5/hr  
min: 8.0E-7/hr  
Source: NUREG 2815 (table C.1.)  
Ultimate source: expert judgement and IREP data  
Comment: Assumes out-of-specification cell replacement

**BTWF1**  battery (power system) wet cell  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: failure to provide proper output  
FAILURE RATE OR PROBABILITY  
mean : 1.0E-6/hr  
ERROR FACTOR: 3  
Source: IREP NUREG 2728 (tb.5.1-1)  
Ultimate source: expert opinion  
Comment: Assumes out-of-specification cell replacement

**BTWF2**  battery (power system) wet cell  
Component boundary: detail n/a  
Operating mode: emergency load condition  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: failure to provide proper output  
FAILURE RATE OR PROBABILITY  
median: 3.0E-6/hr  
95%: 1.0E-5/hr  
5%: 1.0E-6/hr  
ERROR FACTOR: 3  
Source: WASH 1400 (table III 4-2)  
Ultimate source: assessed from industrial, nuclear experience, expert opinion  
Comment: Batteries are constantly charged and their open circuit output voltage is monitored, so failures like shorts to ground or internally are detected quickly. Only significant failure mode is one listed

**BCAF8**  battery charger  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY  
mean : 6.0E-7/hr  
max: 4.0E-6/hr  
min: 3.0E 7/hr  
Source: NUREG 2815 (table C.1.)  
Ultimate source: expert judgement and IREP data  
Comment:
BCAFI battery charger
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 1.0E-6/hr  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:

BCAFZ battery charger
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 5.5E-7/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant specific experience
Comment: Prior:IEEE 500(1977)(pg90) rectifiers,stationary type. Prior failure mode "all modes"
Operating experience: 2.0E+5 hours of operation, no failures

BC1FM battery charger 120 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 6.7E-6/hr  95%: 1.3E-5/hr  5%: 1.7E-6/hr  REPAIR TIME: 5.6 hours
Source: Old PWR  Ultimate source: Generic data updated with plant operating experience
Comment: Generic mean 1.9E-5/hr. Operating experience 2E+5 hours of operation, 1 failure.

BCSFO battery charger SCR type
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 5.0E-6/hr  95%: 1.3E-5/hr  5%: 3.0E-7/hr  REPAIR TIME: 10.1 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500 (1977)(pg93), rec=median; max=95% of distribution. Operating experience: 96.426 hours of operation, 1 failure.
  Repair time is mean of updated component maintenance duration.

BCA battery charger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: hardware failure
FAILURE RATE OR PROBABILITY  mean : 4.0E-4/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1,tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: There is no specific failure mode assigned for this component in the source. ASEP used IREP Procedure Guide value of 1.0E-6/hr assuming monthly system test.
**BCRFE**  
**battery charger rectifier**  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: no output  
**FAILURE RATE OR PROBABILITY**  
rec : 4.9E-7/hr  
high: 1.2E-5/hr  
low: 6.0E-8/hr  
Source: IEEE 500 (1984) pg.66  
Ultimate source: expert opinion aggregation and operating experience  
Comment: Failure rate is composite of different types and voltage levels.

**BCSFN**  
**battery charger solid state general**  
Component boundary: charger, connecting breakers(feeder & output),protect.& controls  
Operating mode: operating  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: no output  
**FAILURE RATE OR PROBABILITY**  
rec : 5.5E-6/hr  
high: 1.8E-5/hr  
low: 1.4E-6/hr  
REPAIR TIME: 5-10 hours  
Ultimate source: operating experience (plant records)  
Comment: Operating experience:total pop.70. Operating time 2,183,975 hours No.of failures 12.  
Repair time is range of medians.

**QBFAE**  
**blower fan**  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: all modes  
Original failure mode: all modes  
**FAILURE RATE OR PROBABILITY**  
rec : 2.5E-6/hr  
high: 2.8E-6/hr  
low: 2.3E-6/hr  
REPAIR TIME: 1.5 hours  
Source: IEEE 500 (1984) pg.1249  
Ultimate source: expert judgement and experience  
Comment: Given value is composite of different sources, different types, designs and applications of fans. (non nuclear application)  
reference:Corps of Engineers,R/M data base; NPRD-2

**QBVAE**  
**blower ventilator air circulating fan**  
Component boundary: detail n/a Include driver  
Operating mode: all  
Operating environment: normal  
Generic failure mode: all modes  
Original failure mode: all modes  
**FAILURE RATE OR PROBABILITY**  
rec : 2.5E-6/hr  
high: 3.4E-6/hr  
low: 1.9E-6/hr  
Source: IEEE 500 (1984) pg.1260  
Ultimate source: expert opinion and experience  
Comment: reference: A/E company "B"

**CBAAB**  
**bus**  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: all modes  
Original failure mode: all modes  
**FAILURE RATE OR PROBABILITY**  
mean : 3.0E-8/hr  
max: 2.0E-7/hr  
min: 6.E-10/hr  
Source: NUREG 2815 (table C.1.)  
Ultimate source: expert judgement and IREP data  
Comment:
CBAAI bus
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.0E-8/hr  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:

CB2FH bus 120 V AC, 220 V AC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 3.4E-7/hr  95%: 6.8E-7/hr  5%: 6.3E-8/hr
Source: Old PWR  Ultimate source: Generic data updated with plant operating experience
Comment: Generic mean 5.0E-7/hr. Operating experience 1.4E+6 hours of operation, no failures.

CB1FH bus 120 V DC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 4.2E-7/hr  95%: 9.2E-7/hr  5%: 6.9E-8/hr
Source: Old PWR  Ultimate source: Generic data updated with plant operating experience
Comment: Generic mean 5.0E-7/hr. Operating experience 4.1E+5 hours of operation, no failures.

CB3FH bus 380 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 3.7E-7/hr  95%: 7.5E-7/hr  5%: 6.3E-8/hr
Source: Old PWR  Ultimate source: Generic data updated with plant specific operating experience
Comment: Generic mean 5.0E-7/hr. Operating experience 9.5E+5 hours of operation, no failures.

CB6FH bus 6 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 4.1E-7/hr  95%: 8.5E-7/hr  5%: 6.6E-8/hr
Source: Old PWR  Ultimate source: Generic data updated with plant operating experience
Comment: Generic mean 5.0E-7/hr. Operating experience 5.4E+5 hours of operation, no failures.
CB5HT

Component boundary: bus bar, measurement Operating mode: operating Operating environment: normal
Generic failure mode: short circuit Original failure mode: short circuit
FAILURE RATE OR PROBABILITY mean: 3.2E-7/hr REPAIR TIME: 8 hours
Source: Swedish Rel.data book, tbl.50 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Op.exp.:total pop.254. Op. time 748E+4 hours, 2 failures. a=0.00952;b=29400. Critical failures ocuried at two plants only. This is only failmode experienced (no interrruption or ground cnts.

CBDF0

Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: operational failure
FAILURE RATE OR PROBABILITY rec: 4.2E-7/hr 95%: 8.3E-7/hr 5%: 3.1E-10/hr REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500(1977)(pg.185), rec=median; max=80% of distribution Operating experience: 2.89E+5 hours of operation, no failures. Repair time is mean of updated maintenance duration (bus or panel)

CBBFE

Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY rec: 2.3E-7/hr high: 2.0E-6/hr low: 4.0E-8/hr
Comment: Reference :IEEE 500 (1977) Failure mode "catastrophic" include open circuit, short line to line and short to ground.

CBAAJ

Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: hardware failure
FAILURE RATE OR PROBABILITY mean: 9.0E-5/d ERROR FACTOR: 5
Source: NUREG 4550, Vol.1 tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: There is no specific failure mode assigned for this component in the source. ASEP used IEEE value of 1.3E-7/hr assuming monthly system test.

CBHFO

Component boundary: bus high voltage, indoor voltage >= 4 kV Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: operational failure
FAILURE RATE OR PROBABILITY mean: 6.2E-7/hr 95%: 1.5E-6/hr 5%: 3.1E-9/hr REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500(1977)(pg.188), rec=median; max=80% of distribution Operating experience: 4.34E+5 hours of operation, no failures. Repair time is mean of updated maintenance duration (4kV bus).
CBIAE  bus insulated switchgear bus 601-15 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 1.9E-7/hr  high: 3.0E-7/hr  low: 1.1E-7/hr
Comment: Reference IEEE 493 (1980)

CBLFO  bus low voltage indoor voltage <= 600 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 1.8E-7/hr  95%: 8.3E-7/hr  5%: 1.8E-9/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500 (1977)(pg.188), rec=median; max=80% of distribution Operating experience:2.17E+6 hours of operation, no failures.

CBMFE  bus metal encloseed
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY  rec : 8.0E-8/hr  high: 4.0E-7/hr  low: 0.0E-0/hr
Comment: Reference: IEEE 500 (1977) Failure mode "catastrophic" include open circut, short line to line and short to ground.

CBM12  bus metal encloseed
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circut  Original failure mode: open circut
FAILURE RATE OR PROBABILITY  mean : 1.9E-8/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Prior: IEEE 500(1977)(pg188), metal enclosed bus.Prior failure mode "open circut"
Operating experience: 3.0E+6 hours of operation, no failures

CCCGE  cable control cable copper conductors
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short to ground  Original failure mode: short line to ground
FAILURE RATE OR PROBABILITY  rec : 2.4E-6/hr  high: 4.4E-6/hr  low: 2.0E-8/hr
Comment: Failure rate per 1000 circuit feet Reference:IEEE 500 (1977)
CCCHE cable control cable copper conductors
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short line to line
FAILURE RATE OR PROBABILITY rec: 1.1E-6/hr  high: 1.9E-6/hr  low: 1.0E-8/hr
Comment: Failure rate is per 1000 circuit feet Reference: IEEE 500 (1977)

CCPIE cable power cable
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open circuit
FAILURE RATE OR PROBABILITY rec: 2.6E-7/hr  high: 1.9E-6/hr  low: 0.0E-0/hr
Source: IEEE 500 (1984) pg.747  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of different types, isolation and voltage levels of power cables.
Failure rate per 1000 circuit feet.

CCPGE cable power cable general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short to ground  Original failure mode: short line to ground
FAILURE RATE OR PROBABILITY rec: 1.2E-6/hr  high: 8.8E-6/hr  low: 0.0E-0/hr
Source: IEEE 500 (1984) pg.747  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of different types, isolation and voltage levels of power cables.
Failure rate per 1000 circuit feet.

CCPHE cable power cable general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short line to line
FAILURE RATE OR PROBABILITY rec: 7.1E-7/hr  high: 5.3E-6/hr  low: 0.0E-0/hr
Source: IEEE 500 (1984) pg.747  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of different types, isolation and voltage levels of power cables.
Failure rate per 1000 circuit feet.

CCSGE cable signal (supervisory) general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short to ground  Original failure mode: short line to ground
FAILURE RATE OR PROBABILITY rec: 2.5E-6/hr  high: 4.3E-6/hr  low: 2.0E-8/hr
Comment: Failure rate per 1000 circuit feet Reference: IEEE 500 (1977)
CCSHE cable signal (supervisory) general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short line to line
FAILURE RATE OR PROBABILITY  rec : 9.5E-7/hr  high: 1.7E-6/hr  low: 1.0E-8/hr
Comment: Failure rate per 1000 circuit feet  Reference: IEEE 500 (1977)

KA4AF circuit breaker 4.16 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 7.1E-7/hr  95%: 1.1E-6/hr  5%: 5.0E-7/hr  ERROR FACTOR: 1.4
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.422. Cum.operating time 25.3E+6 hours. 18 failures. *All modes incl:1)fails short circuit,2)spurious operation,3)other. 2) & 3) about equal. 1)negligable(no failure recorded).
REPAIR TIME: 6 hours

KA4CF circuit breaker 4.16 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate on demand
FAILURE RATE OR PROBABILITY  mean : 5.0E-4/d
Source: HWR data  Ultimate source: HWR assessment
Comment: Operating experience or some other basis for failure rate determination is not provided.

KA4DF circuit breaker 4.16 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY  mean : 4.0E-7/hr  95%: 6.9E-7/hr  5%: 2.4E-7/hr  ERROR FACTOR: 1.6
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.422. Cumulative operating time 25.3E+6 hours. 10 failures.
REPAIR TIME: 6 hours

KA6CH circuit breaker 6 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate on demand
FAILURE RATE OR PROBABILITY  mean : 2.9E-3/d  95%: 6.4E-3/d  5%: 1.0E-3/d
Source: Old PWR  Ultimate source: Generic data updated with plant specific operating experience
Comment: Generic mean 2.3E-3/d. Operating experience 348 demands. 2 failures.
KA6DH  circuit breaker  6 kV  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: fail during operation (transfer open)  
FAILURE RATE OR PROBABILITY  mean : 3.5E-7/hr  95%: 8.1E-7/hr  5%: 3.4E-8/hr  
Source: Old PWR  Ultimate source: Generic data updated with plant operating experience  
Comment: Generic mean 8.3E-7/hr. Operating experience 1.4E+6 hours of operation, no failures.

KALAF  circuit breaker  600 V  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY  mean : 1.9E-7/hr  95%: 3.3E-7/hr  5%: 1.1E-7/hr  ERROR FACTOR: 1.6  REPAIR TIME: 4 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop. 690. Cumulative operating time 43E+6 hours. 8 failures. "All modes" incl: 1) fails short circuit, 2) spurious operation, 3) other. 2) & 3) equal in value, 1) negligible (no failures occurred).

KALCF  circuit breaker  600 V  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: fail to operate on demand  
FAILURE RATE OR PROBABILITY  mean : 5.0E-4/d  
Source: HWR data  Ultimate source: HWR assessment  
Comment: Operating experience or some other basis for failure rate determination is not provided.

KALDF  circuit breaker  600 V  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: spurious operation  
FAILURE RATE OR PROBABILITY  mean : 1.1E-7/hr  95%: 2.2E-7/hr  5%: 4.6E-8/hr  ERROR FACTOR: 2.0  REPAIR TIME: 2 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop. 690. Cumulative operating time 43E+6 hours. 4 failures.

KALCT  circuit breaker  Voltage <= 660 V  
Component boundary: breaker  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to change position  
FAILURE RATE OR PROBABILITY  mean : 1.8E-3/d  95%: 7.3E-3/d  REPAIR TIME: 4 hours  
Source: Swedish Rel. data book, tbl. 53  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERS  
a=0.0299; b=16.3
KALDT  circuit breaker  Voltage <= 660 V
Component boundary: breaker  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious change of position
FAILURE RATE OR PROBABILITY mean : 3.6E-7/hr  REPAIR TIME: 4 hours
Source: Swedish Rel.data book, tbl.53  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience:total pop.730. Operational time 2250E+4 hours. No.of failures 8. Critical failures reported at 4 plants.
\[a=0.0117; b=32900\]

KAMCT  circuit breaker  Voltage between 6 and 10 kV
Component boundary: breaker  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 1.7E-3/d  95%: 4.3E-3/d  REPAIR TIME: 6 hours
Source: Swedish Rel.data book, tbl.52  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience:total pop.278. No.of demands 1760. No.of failures 3. Critical failures occured at 3 plants.
\[a=0.0208; b=12.2\]

KAMD T  circuit breaker  Voltage between 6 and 10 kV
Component boundary: breaker  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious change of position
FAILURE RATE OR PROBABILITY mean : 3.2E-7/hr  95%: 3.8E-7/hr  REPAIR TIME: 6 hours
Source: Swedish Rel.data book, tbl.52  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience:total pop.278. Operational time 932E+4 hours. No.of failures 3. Critical failures occured at 3 plants.
\[a=0.0145; b=45200\]

KAMDU  circuit breaker low voltage (11 kV and below)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY mean : 1.0E-6/hr
Source: Sizewell B (PWR/RX312 pg.14)  Ultimate source: assessed from nuclear and industrial experience nad data
Comment: Assessment based on W data item, literature source and 3 SRS data items.(3.5E-7/hr,op.ex 357E+6 hrs-industnal use)(4.1E-7/hr,op.ex 185E+6hrs)(6.6E-7/hr,op.ex.1.5E+6hrs).

KAMEU  circuit breaker low voltage (11 kV and below)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close on demand
FAILURE RATE OR PROBABILITY mean : 1.0E-6/hr
Source: Sizewell B (PWR/RX312 pg.14)  Ultimate source: assessed from nuclear nad industrial experience and data
Comment: Data sources do not distinguish between failure modes, so the sources and data used to derive givenb value are the same as for circuit breaker spurious operation.
KAMOU  circuit breaker low voltage (11 kV and below)  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to open  Original failure mode: failure to open on demand  
FAILURE RATE OR PROBABILITY  mean : 1.0E-6/hr  
Source: Sizewell B (PWR/RX312 pg.14)  Ultimate source: assessed from nuclear and industrial experience and data  
Comment: Data sources do not distinguish between failure modes, so the sources and data used to derive given value are the same as for circuit breaker spurious operation.

KA400  circuit breaker AC 4 kV  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: transfer open  
FAILURE RATE OR PROBABILITY  mean : 9.9E-8/hr  95%: 2.5E-7/hr  5%: 2.0E-9/hr  
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience  

KA40E  circuit breaker AC 4 kV  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to close  Original failure mode: failure to close  
FAILURE RATE OR PROBABILITY  mean : 8.9E-4/d  95%: 1.6E-3/d  5%: 5.4E-5/d  
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant operating experience  

KA400  circuit breaker AC 4 kV  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to open  Original failure mode: failure to open  
FAILURE RATE OR PROBABILITY  mean : 3.0E-4/d  95%: 6.7E-4/d  5%: 1.5E-5/d  
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience  
Comment: Prior:IEEE 500(1977)(pg.148)."Failure to open" includes combined IEEE modes"fail to open" and "fail to interrupt on opening", rec=median;max=95%of distrib(combined).Op.ex.1192 demands, no failur.

KALDO  circuit breaker AC voltage <= 600 V  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: transfer open  
FAILURE RATE OR PROBABILITY  mean : 4.0E-7/hr  95%: 8.5E-7/hr  5%: 4.5E-8/hr  
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience  
Comment: Prior:IEEE 500(1977)(pg.148), indoor AC c/b.rec=50%;max=80% of dis Failure mode "spurious operation". Same prior as for high volt.cb Operating experience:3.04E+6 operating hours, 2 failures.
KDCDO  circuit breaker DC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer open
FAILURE RATE OR PROBABILITY  mean : 1.8E-7/hr  95%: 4.2E-7/hr  5%: 2.4E-7/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500(1977)(pg150), rec=median; max=80% of distribution. Operating experience: 9.16E+5 hours of operation, no failures.

KBFDZ  circuit breaker bus feed breaker AC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer open
FAILURE RATE OR PROBABILITY  mean : 2.3E-7/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience

KBFEZ  circuit breaker bus feed breaker AC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close on demand
FAILURE RATE OR PROBABILITY  mean : 1.3E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Prior:IEEE 500(1977)(pg.148) AC breaker interior design, fails to close. Operating experience: 3120 demands, 5 failures

KBFOZ  circuit breaker bus feed breaker AC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open on demand
FAILURE RATE OR PROBABILITY  mean : 5.3E-4/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience

KFTAE  circuit breaker fixed type including molden case
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 5.9E-7/hr  high: 3.6E-6/hr  low: 2.5E-7/hr
Source: IEEE 500 (1984) pg.133  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of breakers with different voltage and current levels
KAACB  circuit breaker general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to transfer  
FAILURE RATE OR PROBABILITY  mean: 1.0E-5/hr  max: 5.0E-5/hr  min: 2.0E-7/hr  
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data  
Comment:  

KAACW  circuit breaker general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to transfer  
FAILURE RATE OR PROBABILITY median: 1.0E-3/d  95%: 3.0E-3/d  5%: 3.0E-4/d  ERROR FACTOR: 3  
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data  
Comment: Demand probability is based on presence of proper input signal.  

KAADB  circuit breaker general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: spurious trip  
FAILURE RATE OR PROBABILITY mean: 3.0E-5/hr  max: 2.0E-4/hr  min: 6.0E-7/hr  
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data  
Comment:  

KAADW  circuit breaker general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: premature transfer  
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr  95%: 3.0E-6/hr  5%: 3.0E-7/hr  ERROR FACTOR: 3  
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data  
Comment:  

KA4CI  circuit breaker general size 4 kV and smaller  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to transfer  
FAILURE RATE OR PROBABILITY mean: 3.0E-3/d  ERROR FACTOR: 10  
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion  
Comment:
KA4DI circuit breaker general size 4 kV and smaller
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: spurious trip
FAILURE RATE OR PROBABILITY mean: 3.0E-5/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: For failure mode "spurious trip" rate is given in terms of probability( failures per demand)

KGBOG circuit breaker generator breaker Manufactured by BBC
Component boundary: detail n/a Operating mode: closed Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY median: 6.0E-7/hr ERROR FACTOR: 5
Source: German Risk Study (tb.3,7-1) Ultimate source: operating experience (mainly conventional power plants)
Comment: Operating experience: total pop. 50, 166 years of operation, no failures. Time related rate derived from conventional plants is conservative, because there is much less demands in NPPs.

KGBOT circuit breaker generator breaker Voltage = 20 kV
Component boundary: breaker, local control, central control, surrounding equipment Operating mode: operating (closed) Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY median: 1.1E-2/d 95%: 3.6E-2/d REPAIR TIME: 15
Source: Swedish Rel.data book, tbl.51 Ultimate source: plant operating experience (5 BWR plants)
Comment: Operating experience: total pop. 8. No. of demands 295. No. of failures 3. There is not reported any SPURIOUS FUNCTION of generator breaker in 19E+4 operational hours. $a=0.7; \ b=65$

KAHEG circuit breaker high power (leistungschalter)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY median: 3.0E-7/hr ERROR FACTOR: 6
Source: German Risk Study (tb.3,7-1) Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources. In original text this component is called "Leistungschalter ohne Abzweig", but 'Abzweig" seems to be obsolete.

KAHOG circuit breaker high power (leistungschalter)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY median: 2.0E-7/hr ERROR FACTOR: 11
Source: German Risk Study (tb.3,7-1) Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources. See comment at high power circuit breaker fail to close
KIAAE  circuit breaker indoor AC application
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.4E-7/hr  high: 6.5E-7/hr  low: 2.0E-8/hr
Source: IEEE 500 (1984) pg.120  Ultimate source: expert opinion aggregation and operating experience
Comment: Reference:IEEE 500 (1977)

KIDAE  circuit breaker indoor DC application
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.4E-7/hr  high: 4.0E-7/hr  low: 2.0E-8/hr
Source: IEEE 500 (1984) pg.121  Ultimate source: expert opinion aggregation and experience
Comment: Reference:IEEE 500 (1977)

KISOH  circuit breaker isolation breaker
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY mean : 7.5E-4/d  95%: 2.1E-3/d  5%: 4.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 6.5E-4/d. Operating experience 72 demands, no failures.

KMTAE  circuit breaker metal clad
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 3.4E-7/hr  high: 5.2E-7/hr  low: 2.0E-7/hr
Source: IEEE 500 (1984) pg.141  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of breakers with different voltage and current levels

KCTAE  circuit breaker molded type
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.1E-6/hr  high: 2.9E-6/hr  low: 3.1E-7/hr  REPAIR TIME: 1.1 hours
Source: IEEE 500 (1984) pg.124  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite and include different numbers of poles (1,2,3) and current levels.
KM3DH  circuit breaker motor operated 380 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer open
FAILURE RATE OR PROBABILITY  mean: 1.9E-7/hr  95%: 4.9E-7/hr  5%: 2.4E-8/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 8.3E-7/hr. Operating experience 4.5E+6 hours of operation, no failures.

KOAAE  circuit breaker outdoor AC application
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec: 3.2E-7/hr  high: 1.3E-6/hr  low: 6.0E-8/hr
Source: IEEE 500 (1984) pg.122  Ultimate source: expert opinion aggregation and operating experience
Comment: Reference: IEEE 500 (1977)

KRPOZ  circuit breaker reactor protection breakers
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY  mean: 9.8E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant specific experience
Operating experience:612 demands, 5 failures

JEMFW  clutch mechanical
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  median: 3.0E-4/d  95%: 1.0E-3/d  5%: 1.0E-4/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Demand probability based on presence of proper input signal.

JEEDW  clutch electrical
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: premature disengagement
FAILURE RATE OR PROBABILITY  median: 1.0E-6/hr  95%: 1.0E-5/hr  5%: 1.0E-7/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from industrial and military experience
Comment:
JEEFW clutch electrical
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY median: 3.0E-4/d 95%: 1.0E-3/d 5%: 1.0E-4/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Demand probability is based on presence of proper control signal

QCMRH compressor MSIV air compressor
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 4.3E-3/hr 95%: 5.9E-3/hr 5%: 2.7E-3/hr REPAIR TIME: 4.5 hours
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 9.8E-5/hr. Operating experience 3640 hours of operation, 18 failures. Repair time is mean of 42 maintenance events.

QCMSH compressor MSIV air compressor
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 2.5E-3/d 95%: 4.9E-3/d 5%: 5.9E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 756 demands, 2 failures.

QCCRH compressor containment air control
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 2.5E-3/hr 95%: 4.5E-3/hr 5%: 8.2E-4/hr REPAIR TIME: 39.7 hours
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 9.8E-5/hr. Operating experience 1533 hours of operation, 5 failures. Repair time is mean of 2 maintenance events.

QCCSH compressor containment air control
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 9.9E-3/d 95%: 2.0E-2/d 5%: 2.3E-3/d
Source: Old PWR Ultimate source: generic data upgraded with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 190 demands, 3 failures.
QCIRH  compressor instrument air
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 3.0E-4/hr  95%: 4.5E-4/hr  5%: 2.8E-4/hr  REPAIR TIME: 35.4 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 9.8E-5/hr. Operating experience 1.3E+5 hours of operation, 48 failures. Repair time is mean of 165 maintenance events (outage of 1). Outage of 2: 3 events, 4.5 hours repair time.

QCISH  compressor instrument air
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 2.4E-2/d  95%: 3.1E-2/d  5%: 1.6E-2/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 948 demands, 24 failures.

QCPRA  compressor pumpback (annulus ventilation)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 2.9E-5/hr  95%: 7.3E-5/hr  5%: 2.8E-6/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 2558 hours of operation, no failures.

QCPSh  compressor pumpback (annulus ventilation)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 1.1E-2/d  95%: 1.5E-2/d  5%: 5.3E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 560 demands, 8 failures.

NKAAE  computational module
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 1.2E-6/hr  high: 5.8E-4/hr  low: 3.0E-8/hr
Comment: Failure rate is composite value of 19 different types of computational modules.
Reference NUREG 2232 (1980)
OCR2W control rod
Component boundary: detail n/a  Operating mode: standby  Operating environment: reactor
Generic failure mode: fail to insert  Original failure mode: failure to insert
FAILURE RATE OR PROBABILITY median: $1.0 \times 10^{-4}/d$  95%: $3.0 \times 10^{-4}/d$  5%: $1.0 \times 10^{-5}/d$  ERROR FACTOR: 3
Source: WASH 1400  (table III 4-1)  Ultimate source: assessed from US nuclear operating experience
Comment: Given value is for single scram rod.

OCSAE control rod  clustered silver, indium, cadmium control rods
Component boundary: detail n/a  Operating mode: all  Operating environment:
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : $2.3 \times 10^{-7}/hr$  high: $4.0 \times 10^{-7}/hr$  low: $1.1 \times 10^{-7}/hr$  REPAIR TIME: 120 hours
Comment: reference: NUREG 2232

OCCAE control rod  cruciform, boron carbide control rods
Component boundary: detail n/a  Operating mode: all  Operating environment:
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : $2.3 \times 10^{-7}/hr$  high: $4.0 \times 10^{-7}/hr$  low: $1.1 \times 10^{-7}/hr$
Comment: reference: NUREG 2232 cruciform rods are found in Indian Point 1, Palisades, Yankee Rowe

OCB4T control rod  BWR application
Component boundary: detail n/a  Operating mode: alternating  Operating environment:
Generic failure mode: control rod failure  Original failure mode: control rod failure
FAILURE RATE OR PROBABILITY mean : $2.8 \times 10^{-5}/d$
Source: Swedish Rel.data book, tbl.26  Ultimate source: plant operating experience(7 BWR plants)
Comment: Total pop. 918. No.of demands per operational time 36091. no.of failures 1. (at one plant only). $a=0.00128; b=46.1$

OCK2G control rod  KWU PWR type
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to insert  Original failure mode: failure to insert
FAILURE RATE OR PROBABILITY mean : $2.0 \times 10^{-7}/hr$  ERROR FACTOR: 4
Source: German Risk Study (pg.3-90)  Ultimate source: german plants operating experience
Comment: Operating experience: 5.1E+6 control rod hours, no reported failures. Per demand probability is $7.0 \times 10^{-5}/d$ (EF 4), calculated from about 14000 insertions without failures.
OCR2H  control rod single control rod assembly
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to insert  Original failure mode: fail to fully insert on demand
FAILURE RATE OR PROBABILITY  mean : 3.0E-5/d  95%: 7.9E-5/d  5%: 2.8E-6/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-5/d. Operating experience 1150 demands, no failsures.

OOB1C  control rod and drive mechanism BWR-s
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: dropped/uncoupled/overtraveled rod  Original failure mode: uncoupled/overtraveled rod
FAILURE RATE OR PROBABILITY  mean : 2.9E-7/hr  95%: 4.1E-7/hr  5%: 2.1E-7/hr
Comment: LERs from 01.72 to 04.78.

OOB3C  control rod and drive mechanism BWR-s (GE)
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: improper movement  Original failure mode: improper rod movement
FAILURE RATE OR PROBABILITY  mean : 9.7E-8/hr  95%: 1.6E-7/hr  5%: 5.1E-8/hr
Comment: failure rate is based on personnel errors only

OOB2C  control rod and drive mechanism BWR-s (GE)
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: fail to insert  Original failure mode: failure to insert during normal shutdown
FAILURE RATE OR PROBABILITY  mean : 2.3E-5/d  95%: 7.1E-3/d  5%: 4.1E-6/d
Source: NUREG 1331 (1980) (pg.218)  Ultimate source: US plant LER reports evaluation
Comment: standby hourly rate is 2.3E-8/hr

OOD2C  control rod and drive mechanism BWR-s (GE)
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: fail to insert  Original failure mode: failure to insert to at least 96% during scram
FAILURE RATE OR PROBABILITY  mean : 5.4E-5/d  95%: 1.0E-4/d  5%: 2.6E-5/d
Comment: w/o command faults. With command faults 1.1E-4/d. Standby hourly rate w/o 7.5E-8, with command 1.5E-7.
ODT3C  control rod and drive mechanism BWR-s (GE)
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: improper movement  Original failure mode: rod fails to move during power changes/testing
FAILURE RATE OR PROBABILITY  mean : 1.8E-6/d  95%: 8.5E-6/d  5%: 9.2E-8/d
Comment: Standby hourly rate 1.1E-8/hr. LERs from 01.72 to 04.78.

ODE2C  control rod and drive mechanism PWR-s
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: fail to insert  Original failure mode: failure to insert to at least 96% during scram
FAILURE RATE OR PROBABILITY  mean : 4.0E-5/d  95%: 1.2E-4/d  5%: 1.1E-5/d
Comment: LERs from 01.72 through 04.78. Standby hourly rate 6.6E-8/hr.

ODE3C  control rod and drive mechanism PWR-s
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: improper movement  Original failure mode: rod fails to move during power changes/testing
FAILURE RATE OR PROBABILITY  mean : 3.1E-5/d  95%: 9.6E-5/d  5%: 5.5E-6/d
Comment: W/o command faults. With command faults 7.6E-4/d. Standby hourly rate w/o 4.2E-8/hr, with command 1.0E-6/hr

ODP1C  control rod and drive mechanism PWR-s
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: dropped/uncoupled/overtraveled rod  Original failure mode: dropped rod
FAILURE RATE OR PROBABILITY  mean : 3.2E-7/hr  95%: 4.8E-7/hr  5%: 2.0E-7/hr
Comment: W/o command faults. With command faults 2.2E-6/hr

ODP2C  control rod and drive mechanism PWR-s
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: fail to insert  Original failure mode: failure to insert during normal shutdown
FAILURE RATE OR PROBABILITY  : n/a  95%: 6.4E-5/d
Source: NUREG 1331 (1980) (pg.218)  Ultimate source: US plant LER reports evaluation
Comment: standby hourly rate 6.3E-8/hr (upper 95% confidence limit) no failures recorded
ODP3C control rod and drive mechanism PWR-s
Component boundary: control rod, drive mechanism, housing, all parts connecting CR & DM  Operating mode: standby  Operating environment:
Generic failure mode: improper movement  Original failure mode: improper rod movement
FAILURE RATE OR PROBABILITY  mean : 2.8E-7/hr  95%: 4.5E-7/hr  5%: 1.6E-7/hr
Comment: failure rate is based on personnel errors only LERs from 01.72. to 04.78.

ORLAE control rod drive lead screw roller nut drive mechanism
Component boundary: detail n/a  Operating mode: all  Operating environment:
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 3.5E-6/hr  high: 4.6E-6/hr  low: 2.1E-6/hr
Comment: reference: NUREG 2232

ORMAE control rod drive magnetic jack latch drive mechanism
Component boundary: detail n/a  Operating mode: all  Operating environment:
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 7.8E-7/hr  high: 1.7E-6/hr  low: 3.9E-7/hr
Comment: reference: NUREG 2232

ORM2T control rod drive BWR application mechanical insertion function
Component boundary: motor, drive nut, drive mechanism, logic, protection, controls  Operating mode: alternating  Operating environment:
Generic failure mode: fail to insert  Original failure mode: failure of mechanical insertion function
FAILURE RATE OR PROBABILITY  mean : 6.6E-4/d  95%: 3.9E-3/d
Source: Swedish Rel.data book, tbl.26  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop. 918. No. of demands per operational time 126453. No. of failures 84. No failures reported of scram and insertion function (occurring simultaneously). a=0.0791; b=119

ORM2T control rod drive BWR application hydraulic scram function
Component boundary: drive mechanism, protection and logic, control equipment  Operating mode: standby  Operating environment:
Generic failure mode: fail to insert  Original failure mode: failure of hydraulic scram function
FAILURE RATE OR PROBABILITY  mean : 2.8E-5/d
Source: Swedish Rel.data book, tbl.26  Ultimate source: plant operating experience (7 BWR plants)
Comment: Total pop. 918. No. of demands per operational time 36091 number of failures 1. Critical failure occurred at one plant only a=0.00167; b=60.1
ORAEE control rod drive general
Component boundary: detail n/a Operating mode: all Operating environment:
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.6E-6/hr high: 4.3E-6/hr low: 1.1E-7/hr
Comment: references: NUREG 1331, NUREG 2232 Given value is composite of different sources and types of CR drives.

UCEAF controller electronic
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 4.9E-6/hr 95%: 8.6E-6/hr 5%: 3.0E-6/hr ERROR FACTOR: 1.6 REPAIR TIME: 8 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Population not known. Cum.operating time 1.8E+6 hours. 9 failures. See failure mode comment controller pneumatic.

UCAAE controller general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 7.1E-7/hr high: 5.6E-4/hr low: 1.0E-8/hr
Source: IEEE 500 (1984) pg.725 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite value of 10 controller types. Reference NUREG 2232 (1980).

UCPAF controller pneumatic
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 6.4E-7/hr 95%: 1.3E-6/hr 5%: 3.3E-7/hr ERROR FACTOR: 1.8 REPAIR TIME: 8 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Population not known. Cum.operating time 7.7E+6 hours. 5 failures. "All modes" to be used instead: 1) fail to operate, 2) spurious, 3) erratic operation. No data available for this failure modes.

ECEFS converter E/S general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 4.2E-6/hr
Source: Shoreham PRA, GE data(tb.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment:
ECSFS converter square root general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY mean : 4.2E-6/hr
Source: Shoreham PRA, GE data (tb.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment:

QDAFB damper
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 1.0E-6/hr max: 5.0E-5/hr min: 2.0E-7/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert judgment and IREP data
Comment:

QDAFI damper
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 3.0E-3/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

GDPAE damper Automatic backdraft, parallel blade
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.2E-6/hr REPAIR TIME: .6 hours
Comment: reference: Corps of engineers R/M data base

GDDAE damper Modulating, opposed blade, 36X48 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.8E-6/hr high: 2.7E-6/hr low: 1.2E-6/hr REPAIR TIME: .6 hours
Comment: reference: Corps of engineers R/M data base
QDTAE damper shut off, two position parallel blade
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.2E-6/hr REPAIR TIME: .6 hours
Comment: reference: Corps of Engineers R/M data base, Ground Stationary equipment, Report No 16, 04/12/73

QDCFZ damper containment fan coolers system
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate on demand
FAILURE RATE OR PROBABILITY mean : 1.9E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
Comment: Prior: NUREG 1363 air operated valves(PWR), failed to operate(mean and WASH 1400 air operated valves,fails to operate(distrib.). Operating experience 1150 demands, 3 failures.

QDMDH damper manual (HVAC)
Component boundary: detail n/a Operating mode: normally open Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean : 3.6E-8/hr 95%: 1.1E-7/hr 5%: 1.6E-9/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.2E-8/hr. Operating experience 9.9E+5 hours of operation, no failures.

DEIAE diesel engine No.2 fuel oil, 4 stroke, in-line
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 6.5E-3/hr high: 6.5E-2/hr low: 6.5E-4/hr
Comment: Reference: NUREG 2232

DEVAE diesel engine No.2 fuel oil, 4 stroke, V block
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 4.7E-3/hr high: 1.0E-2/hr low: 2.0E-3/hr
Comment: reference: NUREG 2232
**DEARU** diesel engine general
Generic failure mode: fail to run. Original failure mode: failure to run given start.
FAILURE RATE OR PROBABILITY: median = 3.0E-4/hr, 95% = 3.0E-3/hr, 5% = 3.0E-5/hr. ERROR FACTOR: 10.
Source: WASH 1400 (table III 4-2). Ultimate source: assessed from industrial experience and expert opinion.
Comment: Diesel engine mentioned in this source is engine used to run emergency AC generator. Because of possible variance in redundancy of aux equipment, failure rate is separated for engine and whole plant.

**DGARB** diesel generator emergency AC
Generic failure mode: fail to run. Original failure mode: failure to run, given start.
FAILURE RATE OR PROBABILITY: mean = 3.0E-3/hr, max = 2.0E-2/hr, min = 6.0E-5/hr.
Source: NUREG 2815 (table C.1.). Ultimate source: expert opinion aggregation and IREP data.
Comment: Failure to run is failure to run for more than 1/2 hour, given start. Failure rate is applicable to emergency condition.

**DGARE** diesel generator emergency AC
Generic failure mode: fail to run. Original failure mode: fails while running.
FAILURE RATE OR PROBABILITY: rec = 1.0E-4/hr, high = 8.0E-5/hr, low = 2.0E-5/hr. REPAIR TIME: 11.5 hours.
Comment: Failure rate is composite value of IEEE 500 (1977) and several nuclear sources including NUREG 1362 (1980).

**DGARG** diesel generator emergency AC
Generic failure mode: fail to run. Original failure mode: failure to run.
FAILURE RATE OR PROBABILITY: mean = 4.5E-3/hr. ERROR FACTOR: 2.
Source: German Risk Study (pg. F3-86). Ultimate source: German plants operating experience.
Comment: Operating experience: 35 units observed for 2.5 years. Exact time known for 11 units (avr. 76 hr/y), 50 hr/y considered for the rest. Total op. time: 3740 hr. No. of failures 17. SHORT OPERATING TIME RATE.

**DGARH** diesel generator emergency AC
Generic failure mode: fail to run. Original failure mode: fail during first hour of operation.
FAILURE RATE OR PROBABILITY: mean = 2.7E-3/hr, 95% = 3.7E-3/hr, 5% = 1.3E-3/hr. REPAIR TIME: 6.8 hours.
Source: Old PWR. Ultimate source: generic data updated with plant operating experience.
Comment: Generic mean 1.7E-2/hr. Operating experience 1177 hours of operation, 2 failures.
DGARI diesel generator emergency AC
Component boundary: SEE failure to start, same source
Operating mode: standby
Operating environment: normal
Generic failure mode: fail to run
Original failure mode: failure to run given start
FAILURE RATE OR PROBABILITY mean: 3.0E-3/hr
ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)
Ultimate source: expert opinion
Comment: Failure to run is failure to run more than 1/2 hour, given start.

DGARJ diesel generator emergency AC
Component boundary: detail n/a
Operating mode: standby
Operating environment: normal
Generic failure mode: fail to run
Original failure mode: failure to run
FAILURE RATE OR PROBABILITY mean: 2.0E-3/hr
ERROR FACTOR: 10
Source: NUREG 4550, Vol.1, tbl.VII.1-2
Ultimate source: assessed from several nuclear data sources
Comment: ASEP used generic value from the Reliability of AC Power System Study (NUREG/CR-2989) which contain industry wide analysis.

DGARR diesel generator emergency AC
Component boundary: detail n/a
Operating mode: standby
Operating environment: normal
Generic failure mode: fail to run
Original failure mode: failure to continue to run
FAILURE RATE OR PROBABILITY mean: 1.4E-3/hr
95%: 2.9E-3/hr
5%: 5.4E-4/hr
Repair time: 20 hours
Source: EPRI NP-2433 (1982) (table 3-1)
Ultimate source: operating experience (utility supplied data) Peach Bottom 2 & 3
Comment: Failure rate is calculated for Peach Bottom 2 & 3 plants only. Total experience 32.9 years. No. of failures 5.

DGART diesel generator emergency AC
Component boundary: DG, control & protection equipment, service systems
Operating mode: standby
Operating environment: normal
Generic failure mode: fail to run
Original failure mode: spurious stop
FAILURE RATE OR PROBABILITY mean: 5.5E-3/hr
95%: 2.4E-2/hr
Repair time: 20 hours
Source: Swedish Rel. data book, tbl.40
Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs,
Comment: Operating experience: total pop. 20. Operational time 1440 hours
No. of failures 8. a=0.338; b=60.8
Critical failures reported on 5 plants.

DGARU diesel generator emergency AC
Component boundary: detail n/a
Operating mode: standby
Operating environment: normal
Generic failure mode: fail to run
Original failure mode: failure to continue operation
FAILURE RATE OR PROBABILITY mean: 3.0E-3/hr
Source: Sizewell B (PWR/RX312 pg.13)
Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data item, WASH 1400 and 3 SRS data items, (3.0E-3/hr)(1.3E-3/hr) op. exp. 8.7E+6 hours) (1.4E-3/hr applicable to average industrial use).
DGARW diesel generator emergency AC
Component boundary: complete diesel generator plant Operating mode: standby Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run given start
FAILURE RATE OR PROBABILITY median: 3.0E-3/hr 95%: 3.0E-2/hr 5%: 3.0E-4/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2) Ultimate source: nuclear and non-nuclear experience
Comment: Repair time is mean maintenance duration. For plant with specific action which limits the outage time to 24 hours, mean maintenance duration is 13 hours.

DGARZ diesel generator emergency AC
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 6.0E-3/hr
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: mean NUREG 1362, DG does not continue to run, w/o command, monthly testing. Distribution WASH 1400, DG failure to run Operating experience: operating time 1340 hours, 6 failures.

DGASA diesel generator emergency AC
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start
FAILURE RATE OR PROBABILITY median: 7.1E-3/d ERROR FACTOR: 4.1
Source: NUREG 4550/Vol.3,tbl.IV.B-1 Ultimate source: Surry NPP operating experience
Comment:

DGASB diesel generator emergency AC
Component boundary: SEE IREP DG failure to start Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean : 6.0E-5/hr max: 4.0E-4/hr min: 3.0E-5/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion aggregation and IREP data
Comment: Failure to start is failure to start, accept load and run for 1/2 hour.

DGASE diesel generator emergency AC
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: fails to start
FAILURE RATE OR PROBABILITY rec : 1.6E-2/cy high: 4.0E-1/cy low: 3.0E-4/hr REPAIR TIME: 11.5 hours
Source: IEEE 500 (1984) pg.1218 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite value of IEEE 500 (1977) and several nuclear sources including NUREG 1362 (1980).
DGASG  diesel generator emergency AC
Component boundary: DG, governor, fuel system, starting system, cooling, controls  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 3.0E-2/hr  ERROR FACTOR: 3
Source: German Risk Study (pg. F3-86)  Ultimate source: German plants operating experience
Comment: Starting failure include failures which happened during initial running time.
Operating experience: ca. 810 demands, 24 failures.

DGASH  diesel generator emergency AC
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY  mean : 1.1E-2/d  95%: 1.5E-2/d  5%: 6.1E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 2.1E-2/d. Operating experience 1068 demands, 11 failures.

DGASI  diesel generator emergency AC
Component boundary: engine, gen. coupling, governor, out. breaker, exciter, lube & fuel oil  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 3.0E-2/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: BOUNDARY contd. starting system, intake and exhaust air. Excluded: starting air compressor and accumulator, fuel storage & transfer load sequencer & synchroiser. Failmode incl. running for 1/2 hour.

DGASJ  diesel generator emergency AC
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 3.0E-2/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1, tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: ASEP used generic value from the Reliability of AC Power System Study (NUREG/CR-2989) which contain industry wide data.

DGASR  diesel generator emergency AC
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  pt.est: 1.7E-2/d
Source: EPRI NP-2433(1982) (table S-1)  Ultimate source: operating experience (plant or utility supplied data, 13 plants)
Comment: Failure per demand is based on 123.5 years of experience and 6910 diesel demands.
DGAST diesel generator emergency AC
Component boundary: DG, protection & control equipment, service systems  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 7.7E-3/d  95%: 2.9E-2/d  REPAIR TIME: 20 hours
Source: Swedish Rel.data book, tbl.40  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 20. No. of demands 2090. No. of failures 16. a=0.552; b=67.7
Critical failures reported on 6 plants.

DGASU diesel generator emergency AC
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 3.0E-2/d
Source: Sizewell B (PWR/RX312 pg.13)  Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data, WASH 1400, and SRS data, 2.6E-2/d out of 1567 demands and 1.3E-2/d out of 5500 demands.

DGASW diesel generator emergency AC
Component boundary: complete plant, including starters, pumps and fueling system  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  median: 3.0E-2/d  95%: 1.0E-1/d  5%: 1.0E-2/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear and industrial experience and data
Comment:

DGASY diesel generator emergency AC
Component boundary: DG, control & protection equipment, service systems  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY  mean : 1.2E-2/d  REPAIR TIME: 8 hours
Source: Swedish Rel.data book, tbl.40  Ultimate source: plant operating experience (1 PWR plant - Ringhals 2), ATV reports
Comment: Operating experience: total pop. 4. No. of demands 492. No. of failures 6. No failures recorded out of 164 operating hours.

DGASZ diesel generator emergency AC
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY  mean : 1.8E-2/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data upgraded with plant operating experience
Comment: Prior: mean NUREG 1362, DG fails to start, w/o command, monthly test Distribution WASH 1400, DG fail to start.
Operating experience 1693 demands, 30 failures.
DG4RN  diesel generator emergency AC 4160 V AC
Component boundary: DG, all local systems and components needed for start & operation  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail to run
FAILURE RATE OR PROBABILITY  rec : 6.5E-3/hr  high: 2.3E-2/hr  low: 2.4E-3/hr  REPAIR TIME: 3-8 hours
Source: NUREG 3831 (1985) (tbl.12)  Ultimate source: operating experience (plant records)
Comment: Failure rate is combined failure modes "fail to run" and "inproper operation" because that way it is comparable with other data sources.

DGXRN*  diesel generator emergency AC 4160 V AC
Component boundary: DG, all local systems and components needed for start & operation  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run*  Original failure mode: fails to run once started
FAILURE RATE OR PROBABILITY  rec : 3.6E-4/hr  high: 1.8E-3/hr  low: 1.6E-4/hr  REPAIR TIME: 3-8 hours
Repar time is the range of median.

DGYRN*  diesel generator emergency AC 4160 V AC
Component boundary: DG, all local systems and components needed for start & operation  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run*  Original failure mode: improper operation
FAILURE RATE OR PROBABILITY  rec : 6.1E-3/hr  high: 2.1E-2/hr  low: 2.2E-3/hr  REPAIR TIME: 3-8 hours

DG4SN  diesel generator emergency AC 4160 VAC
Component boundary: DG, all local systems and components needed for start & operation  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  rec : 2.9E-3/d  high: 1.4E-2/d  low: 4.0E-4/d  REPAIR TIME: 3-8 hours
Repair time is range of medians.

QFVRH  fan containment ventilation fan
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 6.0E-6/hr  95%: 1.1E-5/hr  5%: 1.9E-6/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience.
Comment: Generic mean 7.9E-6/hr. Operating experience 2.6E+5 hours of operation, 1 failure.
QFVSH fan containment ventilation fan
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 3.3E-4/d  95%: 7.8E-4/d  5%: 5.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 873 demands, no failures.

QFCRZ fan cooler containment fan cooler
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 3.5E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant specific experience
Comment: Prior: WASH 1400 electric motor failure to run, extreme environment Operating experience 1.52E+5 hours of operation, no failures.

QFCSZ fan cooler containment fan cooler
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY mean : 1.2E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant specific experience
Comment: Prior: WASH 1400 Electric motor failure to start Operating experience: 1155 demands, 2 failures.
Given value includes motor failures only.

QFCRU fan cooler containment fan coolers
Component boundary: detail n/a  Operating mode: standby  Operating environment: post LOCA/SLB environment
Generic failure mode: fail to run  Original failure mode: failure to continue operation
FAILURE RATE OR PROBABILITY mean : 3.7E-6/hr
Source: Sizewell B (PWR/RX312 pg.14)  Ultimate source: assessed from nuclear experience and data
Comment: The only source cited for the assessment of data is Westinghouse PWR data item.

QFCSU fan cooler containment fan coolers
Component boundary: detail n/a  Operating mode: standby  Operating environment: post LOCA/SLB environment
Generic failure mode: fail to start  Original failure mode: failure to start (or change speed)
FAILURE RATE OR PROBABILITY mean : 2.0E-3/d
Source: Sizewell B (PWR/RX312 pg.14)  Ultimate source: ultimate data source is not known
Comment: Since no data is available for fan coolers fail to start, low pressure motor driven pump data were used. Given value is a standby rate for fans to change from normal to post fault operation.
QFCSO  fan cooler reactor building cooling unit
Component boundary: low speed windings, detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 5.7E-3/d  95%: 1.2E-2/d  5%: 7.8E-4/d  REPAIR TIME: 40.5 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
   Repair time is mean of plant spec. update of maintenance duration.

QFHRO  fan cooler reactor building cooling units
Component boundary: high speed windings, detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 1.2E-5/hr  95%: 2.4E-5/hr  5%: 1.3E-6/hr  REPAIR TIME: 40.5 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: median from NUREG 1635 (1980). Only plants reporting coolers failure were B&W. Data for motors = 5.3E-6/hr and for blower = 7E-6 combined; 7E-6 used as median. Op. experience: 81.351 op. hrs, 1 failure.

QFLRO  fan cooler reactor building cooling units
Component boundary: low speed windings, detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 9.5E-6/hr  95%: 2.4E-5/hr  5%: 4.4E-7/hr  REPAIR TIME: 40.5 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Same prior as for high speed windings. Operating experience: 24.175 hours of operation, no failures.
   Repair time is mean of plant spec. update of maintenance duration.

KSFCG  feeder (ABZWEIG) general
Component boundary: circuit breaker, fuse, connecting cable  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY  median: 1.0E-6/hr  ERROR FACTOR: 10
Source: German Risk Study (tb.F3,7-1)  Ultimate source: expert opinion
Comment: ABZWEIG in German terminology indicate the path which is used to feed the electricity to final consumer (component-pump). It usually consist of circuit breaker, fuse and connecting cables.

YFMAE  filter liquid, mechanical restriction
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 2.7E-6/hr  high: 5.3E-6/hr  low: 1.3E-6/hr
Comment: reference: NUREG 2232
UCFFS flow controller general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY mean: 4.2E-6/hr
Source: Shoreham PRA, GE data (tb.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment:

KTAAF fuse all voltage levels
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 1.1E-6/hr REPAIR TIME: 2 hours
Source: HWR data Ultimate source: not known
Comment: FM "all modes" should be used instead of: 1) premature open 2) fails short circuit, 3) fails open circuit. However, no operational data or other sources which were bases for fail. rate determ. are given.

KTAKB fuse general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: premature open
FAILURE RATE OR PROBABILITY mean: 3.0E-6/hr max: 2.0E-5/hr min: 6.0E-8/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert judgement and IREP data
Comment:

KTAKG fuse general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: premature opening
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr ERROR FACTOR: 10
Source: German Risk Study (tb.F3,7-1) Ultimate source: generic data
Comment:

KTAKI fuse general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: premature open
FAILURE RATE OR PROBABILITY mean: 3.0E-6/hr ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:
KTAKKW fuse general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: premature open
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr  95%: 3.0E-6/hr  5%: 3.0E-7/hr  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from industrial and military experience and data sources
Comment:

KTAOWW fuse general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY median: 1.0E-5/d  95%: 3.0E-5/d  5%: 3.0E-6/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data sources
Comment:

DTGAE gas turbine driven generator emergency AC
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 2.8E-3/cy
Source: IEEE 500 (1984) pg.1225  Ultimate source: expert opinion aggregation and experience
Comment: Source: Gas Turbine Manufacturer A. One cycle=one start attempt

FYAYG gasket
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: leakage
FAILURE RATE OR PROBABILITY median: 4.0E-7/hr  ERROR FACTOR: 8
Source: German Risk Study (tb.F3,7-1)  Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources.

EGSRE generator AC steam turbine driven
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail once started
FAILURE RATE OR PROBABILITY rec : 7.2E-7/hr  high: 1.5E-6/hr  low: 4.0E-8/hr
Source: IEEE 500 (1984) pg.257  Ultimate source: expert opinion aggregation and operating experience
Comment: Reference IEEE 500 (1977)
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<td>generator</td>
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<td>n/a, does not include driver</td>
<td>all</td>
<td>normal</td>
<td>fail to run</td>
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<tr>
<td>EGDSE</td>
<td>generator</td>
<td>DC general</td>
<td>n/a, does not include driver</td>
<td>all</td>
<td>normal</td>
<td>fail to start</td>
<td>rec: 1.3E-7/hr, high: 1.3E-5/hr, low: 0.0E-0/hr</td>
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<td>normal</td>
<td>rupture</td>
<td>mean: 1.9E-6/hr, 95%: 5.0E-6/hr, 5%: 3.2E-7/hr</td>
<td>Old PWR</td>
<td>generic data updated with plant operating experience</td>
</tr>
</tbody>
</table>
HXSTH  heat exchanger secondary component cooling HX
Component boundary: detail n.a  Operating mode: all  Operating environment: normal
Generic failure mode: rupture  Original failure mode: rupture/excessive leakage during operation
FAILURE RATE OR PROBABILITY  mean : 1.7E-6/hr  95%: 3.8E-6/hr  5%: 3.2E-7/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.0E-6/hr. Operating experience 1.36E+5 hours of operation, no failures.

HXHAE  heat exchanger U tube horizontal shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 4.8E-6/hr  95%: 7.6E-6/hr  5%: 2.9E-6/hr
Comment: reference: NUREG 2232

HXHAF  heat exchanger U tube horizontal shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 1.1E-5/hr  95%: 1.9E-5/hr  5%: 6.8E-6/hr
ERROR FACTOR: 1.6 REPAIR TIME: 24 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Component population 107.Cumulative component operating time 90E+4 hours.No.of failures 10.Failure mode"all modes"include:
1)plugged,2)external,3)internal leak, 4)inadequate heat transfer

HXDAE  heat exchanger U tube shell and tube plus steam drum
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 2.7E-6/hr  95%: 2.7E-4/hr  5%: 6.2E-7/hr
Comment: reference: NUREG 2232

HXVAE  heat exchanger U tube vertical shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 9.3E-6/hr  95%: 1.4E-5/hr  5%: 6.5E-6/hr
Comment: reference: NUREG 2232
HXVAF  heat exchanger U tube vertical shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 4.0E-5/hr  95%: 5.2E-5/hr  5%: 3.1E-5/hr  ERROR FACTOR: 1.3  REPAIR TIME: 24 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Component population 98. Cumulative component operating time 105E+4 hours. No. of failures 42. Failure mode "all modes" include:
1) external, 2) internal leak, 3) plugged, 4) inadequate heat transfer

HXA6B  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage (shell)  Original failure mode: shell leak
FAILURE RATE OR PROBABILITY mean : 3.0E-6/hr  max: 2.0E-5/hr  min: 6.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:

HXA6I  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage (shell)  Original failure mode: shell leak
FAILURE RATE OR PROBABILITY mean : 3.0E-6/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert judgement
Comment:

HXA6J  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage (shell)  Original failure mode: Rupture (Leakage)
FAILURE RATE OR PROBABILITY mean : 3.0E-6/hr  ERROR FACTOR: 10
Source: NUREG 4550, Vol.1, tbl.VI11.1-2  Ultimate source: assessed from several nuclear data sources
Comment: ASEP used the generic value from IREP Procedure Guide.

HXA7B  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage (tube)  Original failure mode: tube leak (per tube)
FAILURE RATE OR PROBABILITY mean : 3.0E-9/hr  max: 2.0E-8/hr  min: 6.0E-11/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:
HXA71  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage (tube)  Original failure mode: tube leak (per tube)
FAILURE RATE OR PROBABILITY  mean : 3.0E-9/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert judgement
Comment:

HXAOJ  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: plug  Original failure mode: blockage
FAILURE RATE OR PROBABILITY  mean : 5.7E-6/hr  ERROR FACTOR: 10
Comment: ASEP used generic value from GE's LaSalle's PSA.

HXAYS  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: leakage
FAILURE RATE OR PROBABILITY  mean : 5.7E-6/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

HXAYZ  heat exchanger general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: leakage
FAILURE RATE OR PROBABILITY  mean : 7.1E-7/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data upgraded with plant operating experience
Comment: Prior NPRDS page 34. (mean4.6E-6/hr, distribution engn.judgement) Operating experience 2.36E+5 hours, no failures.Plugged shell and/or tube side=negligible(engn.judgement).8.35E+4 hrs,no failures.

HXCAE  heat exchanger helical coil general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 8.7E-6/hr  high: 5.6E-6/hr  low: 1.4E-6/hr
Source: IEEE 500 (1984) pg.1352  Ultimate source: expert judgement and operating experience
Comment: reference: NUREG 2232 Given value is composite of different helical coil heat exchangers
HXBAF  heat exchanger straight tube horizontal shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 2.0E-5/hr  95%: 2.8E-5/hr  5%: 1.4E-5/hr  ERROR FACTOR: 1.4  REPAIR TIME: 24 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Component population 120. Cumulative component operating time 119E+4 hours. No. of failures 24. Failure mode "all modes" include:
1) plugged, 2) external, 3) internal leak, 4) inadequate heat transfer

HXBAE  heat exchanger straight tube horizontal shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 4.2E-6/hr  high: 7.3E-6/hr  low: 2.1E-6/hr
Source: IEEE 500 (1984) pg.1363  Ultimate source: expert judgement and operating experience
Comment: reference : NUREG 2232

HXZAF  heat exchanger straight tube radiation type
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 4.3E-6/hr  95%: 1.1E-5/hr  5%: 1.9E-6/hr  ERROR FACTOR: 2.1  REPAIR TIME: 24 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Component population 46. Cumulative component operating time 69.8E+4 hours. No. of failures 3. Failure mode "all modes" include:
1) plugged, 2) external, 3) internal leakage, 4) inadequate heat transfer

HXZAE  heat exchanger straight tube radiator type
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 3.2E-6/hr  high: 7.2E-6/hr  low: 1.6E-6/hr
Source: IEEE 500 (1984) pg.1361  Ultimate source: expert judgement and operating experience
Comment: reference : NUREG 2232

HXMAE  heat exchanger straight tube vertical shell and tube
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 2.3E-5/hr  high: 3.7E-5/hr  low: 1.4E-5/hr
Comment: reference : NUREG 2232
**HXMAF**

Heat exchanger straight tubes vertical shell and tube

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: all modes  
Original failure mode: all modes

FAILURES RATES OR PROBABILITY  
mean: 1.1E-4/hr  
95%: 1.5E-4/hr  
5%: 8.3E-5/hr  
ERROR FACTOR: 1.3  
REPAIR TIME: 24

Source: HWR data  
Ultimate source: HWR operating experience

Comment: 
Component population 38. 
Cumulative component operating time 31E+4 hours. 
No. of failures 34. 
Failure mode "all modes" include: 
1) plugged, 2) external, 3) internal leak, 4) inadequate heat transfer

**EHFAE**

Heat tracing pipe heater

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: fail to function  
Original failure mode: failed to heat

FAILURES RATES OR PROBABILITY  
mean: 5.6E-7/hr  
high: 1.6E-6/hr  
low: 2.0E-7/hr

Source: IEEE 500 (1984) pg.310  
Ultimate source: expert opinion aggregation and operating experience

Comment: 
Failure rate is composite of two sources. 
Reference: IEEE 500(1977) and NUREG 2232 (1980)

**EHASF**

Heater air heater general

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: overheated  
Original failure mode: overheated

FAILURES RATES OR PROBABILITY  
mean: 2.5E-7/hr  
high: 3.6E-6/hr  
low: 1.0E-8/hr  
REPAIR TIME: 1.5 hours

Ultimate source: expert opinion aggregation and operating experience

Comment: Failue rate is composite of different types and sizes of heaters and different sources including non-nuclear sources.

**EHFAE**

Heater air heater general

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: fail to function  
Original failure mode: failed to heat

FAILURES RATES OR PROBABILITY  
mean: 1.1E-4/hr  
high: 1.6E-5/hr  
low: 7.0E-8/hr  
REPAIR TIME: 1.5 hours

Ultimate source: expert opinion aggregation and operating experience

Comment: Failure rate is composite of different types and sizes of heaters and different sources including non-nuclear application.

**JHFAE**

Heater feedwater heater

Component boundary: detail n/a  
Operating mode: operating  
Operating environment: normal

Generic failure mode: all modes  
Original failure mode: all modes

FAILURES RATES OR PROBABILITY  
mean: 1.3E-5/hr  
REPAIR TIME: 54 hours

Source: IEEE 500 (1984) pg.1387  
Ultimate source: expert judgement and experience

Comment: Reference: Nuclear unit productivity analysis, EPRI report No 46
EHPFE heater pressurizer heater
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY  rec : 2.2E-6/hr
Comment: Catastrophic failure mode include "Won't heat" and "Other" failure modes.
Reference: NUREG 2232 (1980)

QVARH hvac unit annulus ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 6.2E-5/hr  95%: 7.9E+5/hr  5%: 4.4E-5/hr  REPAIR TIME: 21.6 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 7.9E-6/hr. Operating experience 4.2E+5 hours of operation, 31 failure. Repair time is mean of 59 maintenance events.

QVXRH hvac unit auxiliary building
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 6.1E-5/hr  95%: 7.4E-5/hr  5%: 4.5E-5/hr  REPAIR TIME: 10 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 7.9E-6/hr. Operating experience 3.5E+5 hours of operation, 22 failures. Repair time is mean of 77 maintenance events.

QVXSH hvac unit auxiliary building
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 1.9E-3/d  95%: 3.7E-3/d  5%: 4.2E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 635 demands, 3 failures.

QVBRH hvac unit battery room ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 7.2E-6/hr  95%: 1.2E-5/hr  5%: 2.9E-6/hr  REPAIR TIME: 5.1 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 7.9E-6/hr. Operating experience 2.7E+5 hours of operation, 2 failures. Repair time is mean of maintenance events.
QVBSH  hvac unit battery room ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 4.0E-4/d  95%: 8.7E-4/d  5%: 5.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 376 demands, no failures.

QVCRH  hvac unit cable spreading room
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 9.3E-6/hr  95%: 1.7E-5/hr  5%: 3.4E-6/hr  REPAIR TIME: 5.1 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 7.9E-6/hr. Operating experience 1.4E+5 hours of operation, 2 failures. Repair time is mean of 6 maintenance events.

QVCSH  hvac unit cable spreading room
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 4.3E-4/d  95%: 1.0E-3/d  5%: 5.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 189 demands, no failures.

QVRRH  hvac unit control room ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 3.5E-5/hr  95%: 4.7E-5/hr  5%: 1.5E-5/hr  REPAIR TIME: 46.9 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 9.4E-5/hr. Operating experience 1.7E+5 hours of operation, 4 failures. Repair time is mean of 7 maintenance events.

QVRSN  hvac unit control room ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 5.5E-3/d  95%: 9.6E-3/d  5%: 1.4E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 8.1E-3/d. Operating experience 394 demands, 2 failures.
QVREN hvac unit electric equipment area ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 7.4E-5/hr  95%: 9.6E-5/hr  5%: 4.9E-5/hr  REPAIR TIME: 28.6 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 7.9E-6/hr. Operating experience 2.6E+5 hours of operation, 21 failures. Repair time is mean of 50 maintenance events.

QVESH hvac unit electrical equipment area ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 3.1E-4/d  95%: 7.8E-4/d  5%: 5.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 1174 demands, no failures.

QVIRN hvac unit intermediate building
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 1.6E-5/hr  95%: 3.0E-5/hr  5%: 4.5E-6/hr  REPAIR TIME: 25 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 7.9E-6/hr. Operating experience 1.4E+5 hours of operation, 4 failures. Repair time is mean of maintenance events

QVISH hvac unit intermediate building
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 4.3E-4/d  95%: 1.0E-3/d  5%: 5.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 207 demands, no failures

QVASH hvac unit annulus ventilation
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 2.2E-4/d  95%: 4.5E-4/d  5%: 4.4E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.8E-4/d. Operating experience 3189 demands, no failures.
UIEFT indicating instrument electronic general
Component boundary: not clear Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: faulty measurement
FAILURE RATE OR PROBABILITY mean: 7.7E-7/hr 95%: 3.1E-6/hr REPAIR TIME: 2 hours
Source: Swedish Rel. data book, tbl.39 Ultimate source: plant operating experience (7 BWR plants), AIV reports, LERs
Comment: Operating experience: total pop. 280. Operational time 1040E+4 hours. No. of failures 8. a=0.0315; b=41100
Critical failures reported on 5 plants.

IAABW instrumentation general
Component boundary: includes transmitter, amplifier and output device Operating mode: all Operating environment: normal
Generic failure mode: degraded Original failure mode: shift in calibration
FAILURE RATE OR PROBABILITY median: 1.0E-5/hr 95%: 1.0E-4/hr 5%: 1.0E-6/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from military experience and data and testing facilities
Comment: The data for shift in calibration incorporate a variation of drift magnitude, and may be very pessimistic if used for instrumentation with wide tolerance bands.

IAAFI instrumentation general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 3.0E-6/hr ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

IAAFW instrumentation general
Component boundary: includes transmitter, amplifier and output device Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr 95%: 1.0E-5/hr 5%: 1.0E-7/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: The relatively large error factor associated with instrumentation reflects wide variation in configuration from application to application.

ICCBM instrumentation channel analog core flux
Component boundary: Complete instr.channel(sensor,transmitter,cond.system,bistable) Operating mode: operating Operating environment: normal
Generic failure mode: degraded Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean: 5.8E-6/hr 95%: 6.4E-6/hr 5%: 5.3E-6/hr
Comment: Overall rate, with command faults. W/o command faults 5.3E-6/hr
ICFM instrumentation channel analog core flux
Component boundary: Complete instr.channel(sensor,transmitter,cond.system,bistable)  
Generic failure mode: fail to function  
Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 8.2E-6/hr  
95%: 9.0E-6/hr  
5%: 7.5E-6/hr
Ultimate source: US plants LER reports evaluation
Comment: Overall rate with command faults. W/o command faults 7.5E-6/hr.

ICFM instrumentation channel analog flow
Component boundary: complete instr.channel(sensor,transmitter,cond.system,bistable)  
Generic failure mode: degraded  
Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean: 5.2E-6/hr  
95%: 6.2E-6/hr  
5%: 4.3E-6/hr
Ultimate source: US plants LER reports evaluation
Comment: Overall rate with command faults. W/o command faults 4.9E-6/hr.

ICFM instrumentation channel analog flow
Component boundary: complete instr.channel(sensor,transmitter,cond.system,bistable)  
Generic failure mode: fail to function  
Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 4.5E-6/hr  
95%: 5.4E-6/hr  
5%: 3.8E-6/hr
Ultimate source: US plants LER reports evaluation
Comment: Overall rate with command faults. W/o command faults 4.2E-6/hr. PWR rate about 4 times higher than BWR.

ICFM instrumentation channel analog level
Component boundary: complete instr.channel(sensor,transmitter,cond.system,bistable)  
Generic failure mode: degraded  
Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean: 6.7E-6/hr  
95%: 8.0E-6/hr  
5%: 5.6E-6/hr
Ultimate source: US plants LER reports evaluation
Comment: Not applicable to BWR. Overall PWR rate with command faults. W/o command faults 6.2E-6/hr.

ICFM instrumentation channel analog level
Component boundary: complete instr.channel(sensor,transmitter,cond.system,bistable)  
Generic failure mode: fail to function  
Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 4.5E-6/hr  
95%: 5.4E-6/hr  
5%: 3.8E-6/hr
Ultimate source: US plants LER reports evaluation
Comment: Not applicable to BWR. Overall PWR rate with command faults. W/o command faults 4.1E-6/hr.
ICPB Instrumentation channel analog pressure
Component boundary: complete instr.channel(sensor, transmitter, cond.system, bistable) Operating mode: operating Operating environment: normal
Generic failure mode: degraded Original failure mode: reduced capacity
FAILURE RATE OR PROBABILITY mean: 8.2E-6/hr 95%: 9.8E-6/hr 5%: 6.8E-6/hr
Comment: Not applicable to BWR. Overall PWR rate with command faults. W/o command faults 7.8E-6/hr.

ICPFM Instrumentation channel analog pressure
Component boundary: complete instr.channel(sensor, transmitter, cond.system, bistable) Operating mode: operating Operating environment: normal
Generic failure mode: fail to function Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 4.6E-6/hr 95%: 6.0E-6/hr 5%: 3.5E-6/hr
Comment: Not applicable to BWR. Overall PWR rate with command faults. W/o command faults 3.8E-6/hr.

ICTBM Instrumentation channel analog temperature
Component boundary: complete instr.channel(sensor, transmitter, cond.system, bistable) Operating mode: operating Operating environment: normal
Generic failure mode: degraded Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean: 6.8E-6/hr 95%: 8.8E-6/hr 5%: 5.2E-6/hr
Comment: Not applicable to BWR. Overall PWR rate with command faults. W/o command faults 6.7E-6/hr.

ICTFM Instrumentation channel analog temperature
Component boundary: complete instr.channel(sensor, transmitter, cond.system, bistable) Operating mode: operating Operating environment: normal
Generic failure mode: fail to function Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 1.4E-5/hr 95%: 1.7E-5/hr 5%: 1.2E-5/hr
Comment: Not applicable to BWR. Overall PWR rate with command faults. W/o command faults 1.3E-5/hr.

IDLBH Instrumentation channel digital level
Component boundary: level switch Operating mode: operating Operating environment: normal
Generic failure mode: degraded Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean: 8.3E-6/hr 95%: 1.0E-5/hr 5%: 6.9E-6/hr
Comment: Level switch is considered a channel. Not applicable to PWR. BWR rate with command faults. W/o command faults 6.8E-6/hr.
IDLFM  instrumentation channel digital level
Component boundary: level switch  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: inoperable
FAILURE RATE OR PROBABILITY  mean : 2.7E-6/hr  95%: 3.8E-6/hr  5%: 1.9E-6/hr
Comment: Level switch is considered a channel. Not applicable to PWR. BWR rate with command faults. W/o command faults 2.4E-6/hr.

IDPBM  instrumentation channel digital pressure
Component boundary: pressure switch  Operating mode: operating  Operating environment: normal
Generic failure mode: degraded  Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY  mean : 7.3E-6/hr  95%: 8.0E-6/hr  5%: 6.6E-6/hr
Comment: Pressure switch is considered a channel. Overall rate with command faults. W/o command faults 7.1E-6/hr. BWR rate about 5 times higher than PWR.

IDPPM  instrumentation channel digital pressure
Component boundary: pressure switch  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: inoperable
FAILURE RATE OR PROBABILITY  mean : 4.1E-7/hr  95%: 7.0E-7/hr  5%: 2.3E-7/hr
Comment: Pressure switch is considered a channel. Overall rate with command faults. W/o command faults 3.7E-7/hr. BWR rate is twice PWR rate.

IOTSH  intake screen service water system
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: plug  Original failure mode: plugged during operation
FAILURE RATE OR PROBABILITY  mean : 3.7E-6/hr  95%: 9.0E-6/hr  5%: 6.5E-7/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 6.2E-6/hr. Operating experience 1.36E+5 hours of operation, no failures.

EIAAJ  inverter general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: hardware failure
FAILURE RATE OR PROBABILITY  mean : 4.0E-2/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1,tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: There is no specific failure mode assigned for this component in the source. ASEP used IPRD (NUREG 3831) value of 1.0E-4/hr assuming monthly system test.
**EIAFB**  inverter general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY  mean : 6.0E-5/hr  max: 4.0E-4/hr  min: 3.0E-5/hr  
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data  
Comment: 

**EIAFI**  inverter general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY  mean : 1.0E-4/hr  ERROR FACTOR: 3  
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion  
Comment: 

**EIAFZ**  inverter general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: fail during operation  
FAILURE RATE OR PROBABILITY  mean : 1.1E-5/hr  
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience  
Comment: Prior: WASH 1400, solid state devices, high power application failure mode "fails to function". Operating experience: 3.04E+5 hours of operation, 3 failures. 

**EIIFO**  inverter instrument inverter  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: operational failure  
FAILURE RATE OR PROBABILITY  mean : 4.3E-5/hr  95%: 4.8E-5/hr  5%: 4.9E-6/hr  
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience  
Comment: Not possible to identify prior source. Prior mean 1.3E-4/hr. Oper exp:3.37E+5 hours of operation, 9 failures. 

**EISFN**  inverter solid state 120 volts AC  
Component boundary: inverter,transfer switch,rectifier,feeder breaker,prot.& control  Operating mode: operating  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: no output  
FAILURE RATE OR PROBABILITY  rec : 2.1E-5/hr  high: 1.9E-4/hr  low: 8.5E-6/hr  
Comment: Operating experience:total pop.31. Operating time 985.505 hours No.of failures 21. Repair time is range of medians.
EISFT inverter static
Component boundary: inverter, reversing switch, associated cables, transformer, breaker
Operating mode: operating
Operating environment: normal
Generic failure mode: fail to function
Original failure mode: loss of effective output
FAILURE RATE OR PROBABILITY
mean: $5.2 \times 10^{-6}$/hr
95%: $2.6 \times 10^{-5}$/hr
REPAIR TIME: 13 hours
Source: Swedish Rel.data book, tbl.43
Ultimate source: plant operating experience (4 BWR plants), ATV reports, LERs
Comment: Operating experience: Total pop. 10. Operational time $3.85 \times 10^4$ hours. No. of failures 2. Only one critical failure; $a=0.224; b=43100$

EISFY inverter static
Component boundary: inverter, reversing switch, associated cables, transformer, breaker
Operating mode: operating
Operating environment: normal
Generic failure mode: fail to function
Original failure mode: loss of effective output
FAILURE RATE OR PROBABILITY
mean: $1.2 \times 10^{-5}$/hr
REPAIR TIME: 11 hours
Source: Swedish Rel.data book, tbl.43
Ultimate source: plant operating experience (Ringhals 2 PWR)
Comment: Operating experience: Total pop. 4. Total operational time $1.73 \times 10^4$ hours. No. of failures 2.

EIZFE inverter static single phase
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: fail to function
Original failure mode: no output
FAILURE RATE OR PROBABILITY
rec: $1.0 \times 10^{-6}$/hr
high: $1.2 \times 10^{-5}$/hr
low: $3.0 \times 10^{-7}$/hr
Source: IEEE 500 (1984) pg.276
Ultimate source: expert opinion aggregation and operating experience
Comment: Reference IEEE 500 (1977)

EIXFE inverter static three phase
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: fail to function
Original failure mode: no output
FAILURE RATE OR PROBABILITY
rec: $3.0 \times 10^{-6}$/hr
high: $3.0 \times 10^{-5}$/hr
low: $1.9 \times 10^{-7}$/hr
Source: IEEE 500 (1984) pg.277
Ultimate source: expert opinion aggregation and operating experience
Comment: Reference IEEE 500 (1977)

UEYFO isolating diode assembly
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: fail to function
Original failure mode: operational failure
FAILURE RATE OR PROBABILITY
mean: $3.7 \times 10^{-6}$/hr
95%: $6.8 \times 10^{-6}$/hr
5%: $4.1 \times 10^{-7}$/hr
Source: Oconee NPP PRA (tbl.b-1.)
Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: Diode, high power application, MIL-HDBK 217C, all failure modes. High power value =20Xlow power value. Operating experience: $3.86 \times 10^5$ hours of operation, 1 failure.
<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Operating Mode</th>
<th>Operating Environment</th>
<th>Generic Failure Mode</th>
<th>Original Failure Mode</th>
<th>Failure Rate or Probability</th>
<th>Source</th>
<th>Ultimate Source</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>JLCFS</td>
<td>lube oil cooler</td>
<td>all</td>
<td>normal</td>
<td>fail to function</td>
<td>fails to operate</td>
<td>1.5E-6/hr</td>
<td>Shoreham PRA, GE data (tb.A.2-1)</td>
<td>Evaluation of BWR operating experience</td>
<td></td>
</tr>
<tr>
<td>UMCFM</td>
<td>manual control device pushbutton</td>
<td>all</td>
<td>normal</td>
<td>fail to function</td>
<td>fail to operate</td>
<td>2.3E-7/hr REPAIR TIME: 3 hours</td>
<td>HWR data</td>
<td>HWR assessment</td>
<td>Ultimate data source not known. Number of demands in time not known. Repair time conservatively estimated to be 3 hours.</td>
</tr>
<tr>
<td>UMCKF</td>
<td>manual control device pushbutton</td>
<td>all</td>
<td>normal</td>
<td>spurious function</td>
<td>spurious operation</td>
<td>1.1E-7/hr</td>
<td>HWR data</td>
<td>HWR assessment</td>
<td>Ultimate data source not known. Number of demands in time not known.</td>
</tr>
<tr>
<td>MPHAF</td>
<td>motor HP emergency coolant injection pump motor</td>
<td>standby</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>1.7E-5/hr 95%: 2.9E-5/hr 5%: 1.1E-5/hr ERROR FACTOR: 1.6 REPAIR TIME: 223 hours</td>
<td>HWR data</td>
<td>HWR operating experience</td>
<td>Population not known. Cumulative component operating time 63.9E4 hours. 11 failures.</td>
</tr>
<tr>
<td>MPLAF</td>
<td>motor LP emergency coolant injection pump motor</td>
<td>standby</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>1.0E-5/hr 95%: 2.1E-5/hr 5%: 5.7E-6/hr ERROR FACTOR: 1.8 REPAIR TIME: 210 hours</td>
<td>HWR data</td>
<td>HWR operating experience</td>
<td>Population not known. Cumulative component operating time 57.5E4 hours. 6 failures.</td>
</tr>
</tbody>
</table>
MP SAF motor LP service water pump motor
Component boundary: detail n/a     Operating mode: alternating     Operating environment: normal
Generic failure mode: all modes     Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 9.8E-6/hr     95%: 2.1E-5/hr     5%: 5.1E-6/hr
Source: HWR data     Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 51.1E+4 hours. 5 failures.
ERROR FACTOR: 1.9     REPAIR TIME: 200 hours

MP FAF motor auxiliary boiler feed pump motor
Component boundary: detail n/a     Operating mode: standby     Operating environment: normal
Generic failure mode: all modes     Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 1.1E-5/hr     95%: 1.5E-5/hr     5%: 8.6E-6/hr
Source: HWR data     Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 2.7E+6 hours. 31 failures.
ERROR FACTOR: 1.3     REPAIR TIME: 274 hours

MPC AF motor circulating water pump motor
Component boundary: detail n/a     Operating mode: running     Operating environment: normal
Generic failure mode: all modes     Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 7.7E-6/hr     95%: 1.8E-5/hr     5%: 3.8E-6/hr
Source: HWR data     Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 51.9E+4 hours. 4 failures.
ERROR FACTOR: 2.0     REPAIR TIME: 452 hours

MPE AF motor condensate extraction pump motor
Component boundary: detail n/a     Operating mode: running     Operating environment: normal
Generic failure mode: all modes     Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 2.5E-6/hr     95%: 3.6E-6/hr     5%: 1.7E-6/hr
Source: HWR data     Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 7.7E+6 hours. 19 failures.
ERROR FACTOR: 1.4     REPAIR TIME: 161 hours

MP ZAF motor emergency service water pump motor
Component boundary: detail n/a     Operating mode: standby     Operating environment: normal
Generic failure mode: all modes     Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 8.0E-6/hr     95%: 1.2E-5/hr     5%: 5.5E-6/hr
Source: HWR data     Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 2.3E+6 hours. 18 failures.
ERROR FACTOR: 1.4     REPAIR TIME: 150 hours
MPXAF  motor end shield tank cooling pump motor
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.3E-5/hr  95%: 2.7E-5/hr  5%: 6.8E-6/hr  ERROR FACTOR: 1.9  REPAIR TIME: 211 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative operating time 38E+4 hours. 5 failures.

MPBAF  motor generator main lube oil pump motor
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.3E-5/hr  95%: 2.8E-5/hr  5%: 6.8E-6/hr  ERROR FACTOR: 1.9  REPAIR TIME: 211 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative operating time 38E+4 hours. 5 failures.

MPMAF  motor main moderator pump motor
Component boundary: detail n/a  Operating mode: running  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.5E-5/hr  95%: 3.4E-5/hr  5%: 7.3E-6/hr  ERROR FACTOR: 2.0  REPAIR TIME: 227 hours
Source: HWR data  Ultimate source: WRU operating experience
Comment: Population not known. Cumulative component operating time 27E+4 hours. 4 failures.

MPQAF  motor powerhouse upper level service water pump motor
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.1E-5/hr  95%: 2.4E-5/hr  5%: 5.2E-6/hr  ERROR FACTOR: 2.0  REPAIR TIME: 263 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative operating time 38E+4 hours. 4 failures.

MPQAF  motor primary heat transport feed circuit pump motor
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.1E-5/hr  95%: 2.3E-5/hr  5%: 5.7E-6/hr  ERROR FACTOR: 1.9  REPAIR TIME: 154 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative operating time 45.7E+4 hours. 5 failures.
MPVAF motor primary heat transport pump motor
Component boundary: detail n/a  Operating mode: running  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 1.5E-5/hr  95%: 2.9E-5/hr  5%: 8.7E-6/hr  ERROR FACTOR: 1.7
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 45.6E+4 hours. 7 failures.
ERROR FACTOR: 1.7
REPAIR TIME: 170 hours

MPWAF motor shutdown cooling water pump motor
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 1.6E-5/hr  95%: 3.1E-5/hr  5%: 8.6E-6/hr  ERROR FACTOR: 1.8
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 38E+4 hours. 6 failures.
ERROR FACTOR: 1.8
REPAIR TIME: 184 hours

MACRE motor AC general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail to run once started
FAILURE RATE OR PROBABILITY  rec : 3.2E-6/hr  high: 3.0E-3/hr  low: 1.0E-8/hr  REPAIR TIME: 1.8 hours
Comment: Failure rate is composite of different types and voltage levels.

MAIRE motor AC induction
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail to run once started
FAILURE RATE OR PROBABILITY  rec : 1.2E-6/hr  high: 1.6E-3/hr  low: 1.0E-8/hr
Source: IEEE 500 (1984) pg.229  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of different voltage and power levels.

MASAE motor AC split phase
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 1.6E-6/hr  high: 1.5E-3/hr  low: 1.0E-8/hr
Source: IEEE 500 (1984) pg.242  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of two voltage levels.
<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Operating Mode</th>
<th>Operating Environment</th>
<th>Generic Failure Mode</th>
<th>Original Failure Mode</th>
<th>Failure Rate or Probability</th>
<th>Source</th>
<th>Ultimate Source</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAWAE</td>
<td>motor AC synchronous single phase</td>
<td>Operating mode: all</td>
<td>Operating environment: normal</td>
<td>Generic failure mode: fail to run</td>
<td>Original failure mode: fail to run once started</td>
<td>FAILURE RATE OR PROBABILITY rec : 7.0E-7/hr high: 8.4E-7/hr low: 5.6E-7/hr</td>
<td>IEEE 500 (1984) pg.241</td>
<td>expert opinion aggregation and operating experience</td>
<td>Number of starts in time not known.</td>
</tr>
<tr>
<td>MAWSE</td>
<td>motor AC synchronous single phase</td>
<td>Operating mode: all</td>
<td>Operating environment: normal</td>
<td>Generic failure mode: fail to start</td>
<td>Original failure mode: fail to start</td>
<td>FAILURE RATE OR PROBABILITY rec : 5.5E-7/hr high: 6.6E-7/hr low: 4.4E-7/hr</td>
<td>IEEE 500 (1984) pg.241</td>
<td>expert opinion aggregation and operating experience</td>
<td>Number of starts in time not known.</td>
</tr>
<tr>
<td>MDAE</td>
<td>motor DC general</td>
<td>Operating mode: all</td>
<td>Operating environment: normal</td>
<td>Generic failure mode: all modes</td>
<td>Original failure mode: all modes</td>
<td>FAILURE RATE OR PROBABILITY rec : 1.5E-5/hr high: 3.7E-4/hr low: 1.0E-8/hr</td>
<td>IEEE 500 (1984) pg.245</td>
<td>expert opinion aggregation and operating experience</td>
<td>Failure mode is composite of two types of DC motors</td>
</tr>
<tr>
<td>MPKAF</td>
<td>motor boiler feed pump motor</td>
<td>Operating mode: running</td>
<td>Operating environment: normal</td>
<td>Generic failure mode: all modes</td>
<td>Original failure mode: all modes</td>
<td>FAILURE RATE OR PROBABILITY mean : 1.5E-5/hr 95%: 2.6E-5/hr 5%: 9.5E-6/hr ERROR FACTOR: 1.6 REPAIR TIME: 194 hours</td>
<td>HWR data</td>
<td>HWR operating experience</td>
<td>Population not known. Cumulative operating time 65E+4 hours. 10 failures</td>
</tr>
<tr>
<td>MAARG</td>
<td>motor general</td>
<td>Operating mode: all</td>
<td>Operating environment: normal</td>
<td>Generic failure mode: fail to run</td>
<td>Original failure mode: fail to run</td>
<td>FAILURE RATE OR PROBABILITY median: 2.0E-6/hr ERROR FACTOR: 8</td>
<td>German Risk Study (tb.F3,7-1)</td>
<td>generic data</td>
<td>Failure rate is combination of number of generic data sources including non-nuclear.</td>
</tr>
</tbody>
</table>
MAARS motor general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fails to run given start
FAILURE RATE OR PROBABILITY mean : 1.0E-6/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

MAARW motor general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY median: 1.0E-5/hr  95%: 3.0E-5/hr  5%: 3.0E-6/hr  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Applicable only to motors that function independently of pumps and valves.

MAASG motor general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr  ERROR FACTOR: 8
Source: German Risk Study (tb.F3.7-1)  Ultimate source: generic data
Comment: Failure rate is combination of number of generic data sources, including non nuclear.

MAASW motor general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY median: 3.0E-4/d  95%: 1.0E-3/d  5%: 1.0E-4/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Demand probability is based on presence of proper input signal Applicable only to motors that function independently of pumps and valves.

MAXRW motor general
Component boundary: detail n/a  Operating mode: all  Operating environment: extreme (post accident)
Generic failure mode: fail to run  Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY median: 1.0E-3/hr  95%: 1.0E-2/hr  5%: 1.0E-4/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from military, research & test reactor and limited NPP
Comment: Applicable only to motors that function independently of pumps and valves.
MSSFE  motor servo general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail to position
FAILURE RATE OR PROBABILITY  rec : 2.6E-7/hr  high: 5.5E-7/hr  low: 8.0E-8/hr
Source: IEEE 500 (1984) pg.248  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite.

MSSFE  motor servo general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail to operate on demand
FAILURE RATE OR PROBABILITY  rec : 2.5E-7/hr  high: 5.5E-7/hr  low: 8.0E-8/hr
Source: IEEE 500 (1984) pg.248  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite. Number of demands in time not known.

MGXAE  motor generator
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 4.0E-5/hr  high: 5.6E-5/hr  low: 2.8E-5/hr  REPAIR TIME: 2.5 hours
Source: IEEE 500 (1984) pg.278  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite of two non-nuclear sources. References: Corps of engineers R/M data base and NPRD-2

MGAFH  motor generator AC 220 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 6.3E-6/hr  95%: 1.4E-5/hr  5%: 2.5E-6/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.6E-5/hr. Operating experience 5.4E+5 hours of operation, 3 failures.

MGDFB  motor generator D-C
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 3.0E-6/hr  max: 2.0E-5/hr  min: 6.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:
MGDFI  motor generator D-C
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 3.0E-6/hr ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

MGRFT  motor generator D-C rotating converter
Component boundary: DC motor, generator, excitation, rotation regulator, fuse, cables. Operating mode: operating Operating environment: normal
Generic failure mode: fail to function Original failure mode: loss of effective output
FAILURE RATE OR PROBABILITY mean : 2.1E-5/hr 95%: 7.2E-5/hr REPAIR TIME: 14 hours
Source: Swedish Rel.data book, tbl.44 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: operating experience: total pop. 42. Operational time 147E+4 hours No. of failures 31. a=0.711; b=33700. 2 groups of rot. converters: regulation of main coolant pumps (NNS); supply batt. secured AC net

FXAQB  orifice
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: plug Original failure mode: plug
FAILURE RATE OR PROBABILITY mean : 6.0E-7/hr max: 4.0E-6/hr min: 3.0E-7/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment: Given data are WASH 1400 data as alternate data are not available. WASH data are per demand. Calculated number of demands per unit time is not known.

FXTGQ  orifice, test valve, flow meter
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: plug Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY median: 3.0E-4/d 95%: 1.0E-3/d 5%: 1.0E-4/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: ultimate data source not known
Comment:

FXTTW  orifice, test valve, flow meter
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: rupture
FAILURE RATE OR PROBABILITY median: 1.0E-8/hr 95%: 1.0E-7/hr 5%: 1.0E-9/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from reports and experts opinion
Comment:
EB1FO  panelboard 120 V AC  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: operational failure  
FAILURE RATE OR PROBABILITY  mean : 3.8E-7/hr  95%: 8.3E-7/hr  5%: 3.0E-10/hr  REPAIR TIME: 10.8 hours  
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience  
Comment: Prior:IEEE 500(1977)(pg.185) DC buswork, failmode="failure during operation". Operating experience:3.86E+5 hours, no failures.  
Repair time is mean of updated maintenance duration(bus or panel)

JPEAE  penetration electrical  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY rec : 1.0E-7/hr  
Comment: reference: NUREG 1730

JPPAE  penetration piping  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY rec : 8.0E-8/hr  
Comment: reference NUREG 1730

FSSTF  pipe (nuclear grade) straight section diameter size less than 1 inch  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: rupture  Original failure mode: rupture  
FAILURE RATE OR PROBABILITY  mean : 1.2E-9/hr  95%: 2.0E-9/hr  5%: 7.0E-10/hr  ERROR FACTOR: 1.6  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Population 7.3E+4 meters. Operating time 8.5E+9 meter-hours. No. of failures 10. Data include contribution from all pressure boundary components(nozzle,fittings,valve bodies).

FSMTF  pipe (nuclear grade) straight section diameter sizes between 1 and 6 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: rupture  Original failure mode: rupture  
FAILURE RATE OR PROBABILITY  mean : 7.0E-11/hr  95%: 3.0E-10/hr  5%: 2.0E-11/hr  ERROR FACTOR: 2.8  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Population 13E+4 meters. Operating time 1.5E+10 meter-hrs. 1 failure. Data include contribution from all pressure boundary components(nozzle,fittings,valve bodies).
FS3JW piping <= 3" diameter
Component boundary: pipe section (average length between two discontinuities - valves) Operating mode: all Operating environment: normal
Generic failure mode: rupture/plug Original failure mode: rupture/plug
FAILURE RATE OR PROBABILITY median: 1.0E-9/hr 95%: 3.0E-8/hr 5%: 3.6E-11/hr ERROR FACTOR: 30
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear, industrial experience and expert opinion
Comment: Given value is per pipe section. Given value applicable to standby and active pipes. Assessment based on rupture only.

FSMJW piping > 3" diameter
Component boundary: pipe section (average length between two discontinuities - valves) Operating mode: all Operating environment: normal
Generic failure mode: rupture/plug Original failure mode: rupture/plug
FAILURE RATE OR PROBABILITY median: 1.0E-10/hr 95%: 3.0E-9/hr 5%: 3.6E-12/hr ERROR FACTOR: 30
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear, industrial experience and expert opinion
Comment: Given value is per pipe section. Applicable to high quality piping. Given value applies to standby and active pipes. Assessment based on rupture only.

FE5AE piping elbow 4-6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.9E-5/hr high: 1.9E-3/hr low: 6.3E-7/hr
Comment: reference NUREG 2232

FEATH piping expansion joint
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: rupture/excessive leakage during operation
FAILURE RATE OR PROBABILITY mean : 5.9E-8/hr 95%: 1.7E-7/hr 5%: 1.0E-8/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.6E-6/hr. Operating experience 6.83E+6 hours of operation, no failures.

FE3AE piping expansion joint 3" 400 PSI corrugated steel
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.2E-6/hr
Comment: reference: NUREG 2232
<table>
<thead>
<tr>
<th>Component Type</th>
<th>Failure Modes</th>
<th>Operating Mode</th>
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<th>Generic Failure Mode</th>
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<th>Source</th>
<th>Ultimate Source</th>
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<tr>
<td>FNAAE piping nozzle</td>
<td>all modes</td>
<td>all</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>mean: 1.8E-5/hr high: 2.2E-3/hr low: 1.8E-6/hr</td>
<td>IEEE 500 (1984) pg.1328</td>
<td>expert judgement and experience</td>
<td>Given value is composite of different sizes. reference :NUREG 2232</td>
</tr>
<tr>
<td>FNSQO piping nozzle spray nozzle</td>
<td>plug</td>
<td>all</td>
<td>normal</td>
<td>plugged (50%)</td>
<td>plugged (50%)</td>
<td>mean: 2.4E-4/d 95%: 9.0E-4/d 5%: 9.5E-6/d</td>
<td>Oconee NPP PRA (tbl.b-1.)</td>
<td>engineering judgement, extrapolation of data of small pipe plugging</td>
<td>Applicable to the plugging of approximately 50% of the spray nozzles of the single header. It was assumed that no water flow test are performed to verify that spray nozzles are open.</td>
</tr>
<tr>
<td>FRLAE piping rupture diaphragm 10-16 inches</td>
<td>all modes</td>
<td>all</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>mean: 3.3E-6/hr</td>
<td>IEEE 500 (1984) pg.1327</td>
<td>expert judgement and experience</td>
<td>reference :NUREG 2232</td>
</tr>
<tr>
<td>FSAAE piping straight section general</td>
<td>all modes</td>
<td>all</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>mean: 9.4E-6/hr high: 1.8E-3/hr low: 4.5E-7/hr</td>
<td>IEEE 500 (1984) pg.1314</td>
<td>expert judgement and experience</td>
<td>Given value is composite of different piping sizes. reference NUREG 2232</td>
</tr>
<tr>
<td>FTAAE piping tees general</td>
<td>all modes</td>
<td>all</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>mean: 1.9E-5/hr high: 2.2E-3/hr low: 1.7E-6/hr</td>
<td>IEEE 500 (1984) pg.1321</td>
<td>expert judgement and experience</td>
<td>Given value is composite of different sizes of. reference: NUREG 2232</td>
</tr>
</tbody>
</table>
FTLAE piping thermowell 6-10 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY rec : 1.8E-5/hr high: 7.3E-5/hr low: 1.8E-6/hr  
Comment: reference: NUREG 2232

FWSAE piping welds less than 4" connecting weld  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY rec : 2.2E-5/hr high: 2.3E-3/hr low: 7.6E-6/hr  
Comment: reference: NUREG 2232

EPAFE power supply general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: no output  
FAILURE RATE OR PROBABILITY rec : 1.4E-6/hr high: 2.0E-6/hr low: 3.0E-8/hr  
Comment: Reference IEEE 500 (1977)

EPAFS power supply general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to function  Original failure mode: fails to operate  
FAILURE RATE OR PROBABILITY mean : 4.2E-6/hr  
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience  
Comment:  

PWAAF pump auxiliary boiler feed pump  
Component boundary: detail n/a  Operating mode: standby?  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY mean : 7.6E-5/hr  95%: 1.3E-4/hr  5%: 4.8E-5/hr  ERROR FACTOR: 1.6  REPAIR TIME: 11 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Population: unknown. Cumulative component operating time 14.5E+4 hours. No.of failures 11. FM "all modes" is not defined, but prob. incl:1)external leak, 2)start, 3)run failure, 4)less than rated outp
PWCRE

pump centrifugal
Component boundary: detail n/a. Sometimes include driver. Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: fails while running
FAILURE RATE OR PROBABILITY rec : 7.1E-6/hr high: 5.8E-4/hr low: 0.0E-0/hr
Comment: Given value is composite of several sources, different pump types and sizes and operating modes. More specific data included elsewhere.

PWCS

pump centrifugal
Component boundary: Detail n/a. Sometimes include driver Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: fails to start
FAILURE RATE OR PROBABILITY rec : 4.7E-3/cy high: 2.5E-1/cy low: 0.0E-0/cy
Comment: This value is composite of several sources, different pump types and operating modes. More detailed data are included elsewhere.

PWDBF

pump centrifugal horizontal flow 22-820 l/s
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: degraded Original failure mode: less than rated output
FAILURE RATE OR PROBABILITY mean : 1.5E-5/hr 95%: 2.1E-5/hr 5%: 1.2E-5/hr ERROR FACTOR: 1.3 REPAIR TIME: 18
Source: HWR data Ultimate source: HWR operating experience
Comment: Population 44. Cumulative component operating time 226E+4 hours. 35 failures.

PWDSF

pump centrifugal horizontal flow 22-820 l/s
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: start failure
FAILURE RATE OR PROBABILITY mean : 1.0E-6/hr 95%: 2.7E-6/hr 5%: 3.4E-7/hr ERROR FACTOR: 2.4 REPAIR TIME: 21 hour
Source: HWR data Ultimate source: HWR operating experience
Comment: Number of starts per operational time is not known. Population 44. Component cumulative operational time 226E+4 hours. No. of failures 2.

PWBRF

pump centrifugal horizontal flow 22-820 l/s
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: running failure
FAILURE RATE OR PROBABILITY mean : 6.2E-6/hr 95%: 9.7E-6/hr 5%: 4.1E-6/hr ERROR FACTOR: 1.5 REPAIR TIME: 10 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Population 44. Component cumulative operating time 226E+4 hours. No. of failures 14.
PWBF pump centrifugal horizontal flow 22-820 l/s
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY  mean : 2.4E-5/hr  95%: 3.0E-5/hr  5%: 1.9E-5/hr  ERROR FACTOR: 1.2  
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population 44. Cumulative component operating time 226E+4 hours. 94 failures.

PWEBF pump centrifugal vertical flow 70-1900 l/s
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: less than rated output
FAILURE RATE OR PROBABILITY  mean : 1.4E-5/hr  95%: 1.8E-5/hr  5%: 1.1E-5/hr  ERROR FACTOR: 1.3  
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population 62. Cumulative component operating time 296E+4 hours. 110 failures.

PWRF pump centrifugal vertical flow 70-1900 l/s
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: running failure
FAILURE RATE OR PROBABILITY  mean : 4.0E-6/hr  95%: 7.0E-6/hr  5%: 2.9E-6/hr  ERROR FACTOR: 1.5  
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population 62. Cumulative component operating time 296E+4 hours. 13 failures.

PWESF pump centrifugal vertical flow 70-1900 l/s
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: start failure
FAILURE RATE OR PROBABILITY  mean : 1.0E-6/hr  95%: 1.5E-6/hr  5%: 1.1E-7/hr  ERROR FACTOR: 2.8  
Source: HWR data  Ultimate source: HWR operating experience
Comment: Number of starts per operational time is not known. Population 62. Cumulative component operating time 296E+4 hours. No. of failures 1.

PWEYF pump centrifugal vertical flow 70-1900 l/s
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY  mean : 3.6E-5/hr  95%: 4.3E-5/hr  5%: 3.1E-5/hr  ERROR FACTOR: 1.2  
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population 62. Cumulative component operating time 296E+4 hours. No. of failures 110.
PWFAF

pump condensate extraction pump

Component boundary: detail n/a  Operating mode: running  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 5.5E-5/hr  95%: 6.8E-5/hr  5%: 4.4E-5/hr  ERROR FACTOR: 1.2  REPAIR TIME: 16.3
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population: unknown. Cumulative component operating time 100E+4 hr  No.of failures 55. FM "all modes" is not defined, but probably incl
1) external leak, 2) start, 3) run failure, 4) less than rated output.

PWPRE

pump positive displacement

Component boundary: Variable. Sometimes includes driver.  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fails while running
FAILURE RATE OR PROBABILITY rec : 1.9E-6/hr  high: 2.4E-4/hr  low: 0.00
Comment: Given value is composite of several sources, different pump types and sizes and operating modes. More specific data included elsewhere.

PWPSE

pump positive displacement

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fails to start
FAILURE RATE OR PROBABILITY rec : 1.9E-2/d  high: 1.6E-1/d  low: 0.0  REPAIR TIME: 7.3 hours
Comment: Given value is composite of several sources, different pump types, and operating modes. More detailed data which are given in IEEE500 regarding pumps are included in NUREG 2886 data.

PDAFP

pump diesel driven

Component boundary: incl mech control, governor, emergency tripping, blower, lube oil sys  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: does not operate
FAILURE RATE OR PROBABILITY mean : 1.2E-2/d  95%: 3.5E-2/d  5%: 4.3E-3/d

PDARI

pump diesel driven

Component boundary: pump, diesel, lube oil system, fuel oil, suction and exhaust, starting  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: failure to run given start
FAILURE RATE OR PROBABILITY mean : 8.0E-4/hr  ERROR FACTOR: 30
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:
PDASB  pump diesel driven
Component boundary: Pump,diesel,lube oil system,fuel oil,suction and exhaust,starting
Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 1.0E-6/hr  max: 5.0E-5/hr  min: 2.0E-7/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion aggregation and IREP data
Comment:

PDASD  pump diesel driven
Component boundary: pump,shaft,diesel,local instrumentation and control circuitry  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fails to start
FAILURE RATE OR PROBABILITY  mean : 2.1E-2/d  : 3.0E-1/d  : 4.0E-3/d
Comment: Pop.24. 9 catastrophic demand related failures of 427 demands. Upbound and lowbound are largest and smallest rate of the functional aggregates of selected pumps classified by driver

PDASI  pump diesel driven
Component boundary: pump,diesel,lube oil system,fuel oil,suction and exhaust,starting
Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 1.0E-3/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:

PDASP  pump diesel driven
Component boundary: incl.mech.control,governor,emergency tripping,blower,lube oil sys
Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: does not start
FAILURE RATE OR PROBABILITY  mean : 3.0E-3/d
Comment: Pop.4 (PWR & BWR). 1 failure. W/o command faults W command faults 3.0E-2/d. Standby hourly rate with command faults 6.5E-5/hr

PDCRZ  pump diesel driven containment spray pump
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 2.9E-2/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant experience
Comment: Prior:WASH 1400 pumps (w/o motor),failure to run, normal environ. WASH 1400, Diesel(engine only),failure to run. Operating experience: 33 hours of operation, 2 failures.
PDCSZ  pump diesel driven containment spray pump
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY mean : 4.2E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data upgraded with plant specific experience
Comment: Prior:NUREG 1205(diesel pump,standbyXH),WASH 1400(diesel plant??). (D).Op.exp.183 demands,1 failure. N-1205 population of 4 include 2 ZION diesel pumps and only 1 failure occurring.Failrate too low?

PDASJ  pump diesel driven general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: fails to start
FAILURE RATE OR PROBABILITY mean : 1.0E-3/d ERROR FACTOR: 3
Source: NUREG 4550, Vol.1 tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: ASEP used the generic value from LERs. Failure to start incl two types of failure: circuit breaker command faults (3.0E-2) and pump hardware faults (3.0E-3).

PWWRG pump general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run
FAILURE RATE OR PROBABILITY mean : 2.9E-5/hr ERROR FACTOR: 3.7
Source: German Risk Study (pg.F3-72) Ultimate source: generic data, including non-nuclear application and experience
Comment: 

PWWSG pump general
Component boundary: pump with driver Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean : 1.6E-5/hr ERROR FACTOR: 7
Source: German Risk Study (pg.F3-71) Ultimate source: generic data including non-nuclear application
Comment: Assuming 4 weeks test interval, failure rate is about twice the recorded operational experience.

PMAFP pump motor driven
Component boundary: pumping unit,motor,coupling,mech.control.Excl.MCC,breakers,ect Operating mode: standby Operating environment: normal
Generic failure mode: fail to function Original failure mode: does not operate
FAILURE RATE OR PROBABILITY median: 2.4E-3/d 95%: 1.9E-3/d 5%: 2.8E-3/d
Comment: Failmode incl.:does not start, leak/rupt., loss of funct., does not continue to run.Pop:596; No.of failures:76. W/o command fail. W.com. faults 6.2E-3.Stdbry hourly rate w/o 4.7E-6, W 1.2E-5 per stdbry hr.
PMASP pump motor driven
Component boundary: pumping unit, motor, coupling, mech. control Excl. MCC, breakers, etc. Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: does not start
FAILURE RATE OR PROBABILITY median: 5.1E-4/d 95%: 7.1E-4/d 5%: 3.4E-4/d
Comment: Overall data, includes all types of reactors, LER-s from 1972 to 1980. Total pop. 596. No of failures 91. Wo command faults W command faults 3.0E-3. Stdby hourly rate 1.0E-6

PMASZ pump motor driven
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY mean: 7.2E-4/d
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data upgraded with plant specific experience
Comment: Priors: NUREG 1205 (tbl.14) standby system does not start, w/o comman (mean), and WASH 1400 table III 2-1, electric motor failure to start for distribution. Experience: 3138 demands, 3 failures

PMBRP pump motor driven
Component boundary: pumping unit, coupling, motor, mech. control Excl. MCC, breakers Operating mode: alternating Operating environment: normal
Generic failure mode: fail to run Original failure mode: does not operate given start
FAILURE RATE OR PROBABILITY median: 1.8E-5/hr 95%: 2.0E-5/hr 5%: 1.6E-5/hr
Comment: Overall data (PWR&BWR) LER from 72 to 80. Total pop. 720. No of fail. 110 W/o command faults (w. command faults 2.1E-5). F. mode does not operate incl: leakage/rupt. Is of function, does not cont. to run

PMBSZ pump motor driven
Component boundary: pumping unit, motor, coupling, mech. control Excl. MCC, breakers etc. Operating mode: alternating Operating environment: normal
Generic failure mode: fail to start Original failure mode: does not start
FAILURE RATE OR PROBABILITY median: 3.4E-4/d 95%: 5.1E-4/d 5%: 2.3E-4/d

PMRRP pump motor driven
Component boundary: pumping unit, motor, coupling, mech. control Excl. MCC, breakers etc. Operating mode: running Operating environment: normal
Generic failure mode: fail to run Original failure mode: does not operate given start
FAILURE RATE OR PROBABILITY median: 5.3E-6/hr 95%: 6.9E-6/hr 5%: 4.1E-6/hr
Comment: Overall data (PWR&BWR) LER from 72 to 80. Total pop. 209. No of fail. 12 W/o command faults (w. command faults 1.4E-5). F. mode does not operate incl: leakage/rupt. Is of function, does not cont. to run
PMURB pump motor driven
Component boundary: pump and motor, excludes control circuits Operating mode: all Operating environment: extreme
Generic failure mode: fail to run Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY mean: 3.0E-3/hr max: 2.0E-2/hr min: 6.0E-5/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion aggregation and IREP data
Comment: Extreme operating environment characterise interface with heavy chemical environment-boric acid.

PMURI pump motor driven
Component boundary: pump and motor, excludes control circuits Operating mode: all Operating environment: extreme
Generic failure mode: fail to run Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY mean: 3.0E-3/hr ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: Extreme operating environment characterise interface with heavy chemical environment-boric acid.

PMURW pump motor driven
Component boundary: detail n/e, including motor Operating mode: all Operating environment: extreme, post accident inside containment
Generic failure mode: fail to run Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY median: 1.0E-3/hr 95%: 1.0E-2/hr 5%: 1.0E-4/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from test & research reactors and military experience
Comment:

PMYRB pump motor driven
Component boundary: pump and motor, excludes control circuits Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY mean: 1.0E-4/hr max: 5.0E-4/hr min: 2.0E-6/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion aggregation and IREP data
Comment:

PMYRI pump motor driven
Component boundary: pump and motor, excludes control circuits Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run, given start
FAILURE RATE OR PROBABILITY mean: 3.0E-5/hr ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:
PMYRS pump motor driven
Component boundary: pump and motor Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run
FAILURE RATE OR PROBABILITY mean: 7.9E-6/hr
Source: Shoreham PRA, GE data (tb. A. 2-1) Ultimate source: evaluation of BWR operating experience
Comment: From the data tables it is assumed that the given value include failure for pump to start and to continue running.

PMYRW pump motor driven
Component boundary: detail n/a, include motor Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run given start
FAILURE RATE OR PROBABILITY median: 3.0E-5/hr 95%: 3.0E-4/hr 5%: 3.0E-6/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear, industrial and military experience and data
Comment:

PMYSB pump motor driven
Component boundary: including motor, excluding control circuitry Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean: 1.0E-5/hr max: 5.0E-5/hr min: 2.0E-7/hr ERROR FACTOR: 10
Source: NUREG 2815 (table C. 1.) Ultimate source: expert opinion aggregation & IREP data
Comment:

PMYSI pump motor driven
Component boundary: including motor, excluding control circuitry Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY mean: 3.0E-3/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb. 5.1-1) Ultimate source: expert opinion
Comment:

PMYSW pump motor driven
Component boundary: detail n/a, including motor Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY median: 1.0E-3/d : 3.0E-3/d : 3.0E-4/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear, industrial and military experience and data
Comment:
PMXRZ  pump motor driven auxiliary feedwater  
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: fail during operation  
FAILURE RATE OR PROBABILITY  
mean : 9.9E-5/hr  
Source: ZION NPP PSS (tbl.1.5.1-5)  
Ultimate source: generic data updated with plant specific operating experience  
Comment: Priors: NUREG 1205 alternating system, does not operate given start (mean) and WASH 1400 pump (w/o motor) failure to run (distribution).  
Operating experience: 3800 hours of operation, 1 failure.

PMXSA  pump motor driven auxiliary feedwater  
Component boundary: detail n/a  
Operating mode: standby  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: fail to start/run  
FAILURE RATE OR PROBABILITY  
median: 5.6E-3/d  
ERROR FACTOR: 2.2  
Source: NUREG 4550/Vol.3, tbl.IV.8-1  
Ultimate source: Surry NPP operating experience (test data?)  
Comment: It was not possible to identify failure mode as appear in table. It seems to cover starting failure and initial running failure.

PMXSZ  pump motor driven auxiliary feedwater  
Component boundary: DETAIL n/a  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: failure to start on demand  
FAILURE RATE OR PROBABILITY  
mean : 5.0E-3/d  
Source: ZION NPP PSS (tbl.1.5.1-5)  
Ultimate source: generic data updated with plant specific operating experience  
Comment: Priors: NUREG 1205 (tb.14) standby system, does not start, w/o comm (mean) and WASH 1400 (tbl.III 2-1) electric motor failure to start (distribution). Experience: 462 demands, 4 failures.

PMXRH  pump motor driven auxiliary feedwater pump  
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: fail during operation  
FAILURE RATE OR PROBABILITY  
mean : 5.9E-5/hr  
95%: 1.7E-4/hr  
5%: 8.9E-6/hr  
REPAIR TIME: 5.5 hours  
Source: Old PAR  
Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 3.4E-5/hr. Operating experience 5641 hour of operation, 1 failure. Repair time is mean of 27 maintenance events.

PMXSH  pump motor driven auxiliary feedwater pump  
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: fail to start on demand  
FAILURE RATE OR PROBABILITY  
mean : 5.4E-3/d  
95%: 1.1E-2/d  
5%: 1.5E-3/d  
Source: Old PAR  
Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 3.3E-3/d. Operating experience 424 demands, 3 failures.
**PMHRZ**

- **Component**: Pump motor driven centrifugal charging pump
- **Component boundary**: detail n/a
- **Operating mode**: alternating
- **Operating environment**: normal
- **Generic failure mode**: fail to run
- **Original failure mode**: fail during operation
- **FAILURE RATE OR PROBABILITY**
  - **mean**: 1.8E-6/hr
- **Source**: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
- **Comment**: Priorors: NUREG 1205, Alternating sys., motor driven, does not operate given str(M); WASH 1400, pumps, fail to run, extreme environment (D)
- **Operating experience**: 7.6E+4 hours of operation, no failures

**PMDRT**

- **Component**: Pump motor driven centrifugal horizontal flow rate 130-200 kg/s; head .7 MPa
- **Operating mode**: running
- **Operating environment**: normal
- **Generic failure mode**: fail to run
- **Original failure mode**: spurious stop
- **FAILURE RATE OR PROBABILITY**
  - **mean**: 2.3E-5/hr
  - **95%**: 1.0E-4/hr
- **REPAIR TIME**: 18 hr
- **Source**: Swedish Rel. data book, tbl.2 Ultimate source: plant experience (6 BWR plants), ATV reports, LERs, plant inform.
- **Comment**: Operating experience: total pop. 16. Operating time 18.1E+4 hours. 5 failures. a = 0.315; b = 13800. Critical failures occurred at 3 plants.

**PMOST**

- **Component**: Pump motor driven centrifugal horizontal and vertical flow rate 30 kg/s; head 2.2-6.7 MPa
- **Operating mode**: standby
- **Operating environment**: normal
- **Generic failure mode**: fail to start
- **Original failure mode**: failure to start
- **FAILURE RATE OR PROBABILITY**
  - **mean**: 1.4E-3/d
  - **95%**: 8.3E-3/d
- **REPAIR TIME**: 2 hr
- **Source**: Swedish Rel. data book, tbl.7 Ultimate source: operating experience (7 BWR plants), ATV reports, LERs, plant inform.
- **Comment**: Data derived from observation of 12 components, 696 demands (per op. time), 1 failure occurring (critical)
  - Critical failures occurred at one plant only. a = 0.116; b = 80.3

**PMMRT**

- **Component**: Pump motor driven centrifugal horizontal and vertical flow rate 75-250 kg/s; head .3-.9 MPa
- **Operating mode**: alternating
- **Operating environment**: normal
- **Generic failure mode**: fail to run
- **Original failure mode**: spurious stop
- **FAILURE RATE OR PROBABILITY**
  - **mean**: 1.7E-5/hr
  - **95%**: 8.4E-5/hr
- **REPAIR TIME**: 10 hr
- **Source**: Swedish Rel. data book, tbl.5 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
- **Comment**: Operating experience: Total pop. 66. Operational time 78.6E+4 hours. 13 failures. a = 0.21; b = 12700. Critical failures occurred at 6 plants.

**PMMST**

- **Component**: Pump motor driven centrifugal horizontal and vertical flow rate 75-250 kg/s; head .3-.9 MPa
- **Operating mode**: alternating
- **Operating environment**: normal
- **Generic failure mode**: fail to start
- **Original failure mode**: failure to start
- **FAILURE RATE OR PROBABILITY**
  - **mean**: 3.9E-3/d
  - **95%**: 2.1E-2/d
- **REPAIR TIME**: 10 hr
- **Source**: Swedish Rel. data book, tbl.5 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
- **Comment**: Operating experience: total pop. 66. Other data not known. Critical failures occurred at 6 plants.
PMNRT  pump motor driven centrifugal horizontal flow rate: 40-60 kg/s; head 0.5-0.7 MPa  
Component boundary: pump, transmission, motor, breaker, fuses, protection, controls  
Operating mode: running  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: spurious stop  
FAILURE RATE OR PROBABILITY mean : 2.8E-5/hr  
95%: 1.1E-4/hr  
REPAIR TIME: 11 hr  
Source: Swedish Rel. data book, tbl.1  
Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERS  
Comment: Operating experience: total pop. 14. Operating time 28.8E+4 hours 8 failures. a=0.0527; b=19000. Critical failures occurred at 4 plants.

PMMSY  pump motor driven centrifugal horizontal and vertical flow rate 75-250 kg/s; head 0.3-0.9 MPa  
Component boundary: pump, transmission, motor, breaker, fuses, protection, controls  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: failure to start  
FAILURE RATE OR PROBABILITY mean : 1.4E-3/d  
REPAIR TIME: 24 hr  
Source: Swedish Rel. data book, tbl.5  
Ultimate source: plant operating experience Ringhals 2 PWR  
Comment: 10 components observed, other information not available

PMRRT  pump motor driven centrifugal reactor coolant pump flow rate 1036-2347 kg/s; head 0.3-0.4 MPa  
Component boundary: pump, transmission, motor, breaker, fuses, protection, controls  
Operating mode: running  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: spurious stop  
FAILURE RATE OR PROBABILITY mean : 7.8E-5/hr  
95%: 1.9E-4/hr  
REPAIR TIME: 5 hr  
Source: Swedish Rel. data book, tbl.4  
Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERS  
Comment: Operating experience: total pop. 38. Operating time 112E+4 hours. No. of failures 3. a=0.0671; b=25100. Critical failures occurred at 3 plants.

PMWRT  pump motor driven centrifugal wet flow rate 75-150 kg/s; head 1.3-1.8 MPa  
Component boundary: pump, transmission, motor, breakers, fuses, protection, controls  
Operating mode: running  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: spurious stop  
FAILURE RATE OR PROBABILITY mean : 2.8E-5/hr  
95%: 1.9E-4/hr  
REPAIR TIME: 18 hr  
Source: Swedish Rel. data book, tbl.3  
Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERS  
Comment: Operating experience: total pop 14. Operating time 27.2E+4 hours 19 failures. a=1.93; b=26900. Critical failures occurred at 6 plants.

PMWRY  pump motor driven centrifugal wet flow rate 75-150 kg/s; head 1.3-1.8 MPa  
Component boundary: pump, transmission, motor, breaker, fuse, protection, controls  
Operating mode: running  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: spurious stop  
FAILURE RATE OR PROBABILITY mean : 1.2E-4/hr  
REPAIR TIME: 24 hr  
Source: Swedish Rel. data book, tbl.3  
Ultimate source: plant operating experience, Ringhals 2 PWR  
Comment: Operating experience: total pop 2. Operating time 2.56E+4 hours 3 failures.
### PMRNY
- **Pump Motor Driven Centrifugal**: Horizontal and vertical flow rate 75-250 kg/s; head 0.3-0.9 MPa
- **Component Boundary**: Pump, transmission, motor, breaker, fuses, protection, controls
- **Operating Mode**: Alternating
- **Operating Environment**: Normal
- **Generic Failure Mode**: Fail to run
- **Original Failure Mode**: Spurious stop
- **Failure Rate or Probability (mean)**: 8.1E-5/hr
- **Repair Time**: 24 hr
- **Source**: Swedish Rel.data book, tbl.5
- **Comment**: Ultimate source: Plant operating experience (Ringhals 2 PWR)
- **Operating Experience**: Total pop. 10. Operating time 8.67E+4 hours, 7 failures.

### PMRNY
- **Pump Motor Driven Centrifugal**: Horizontal flow rate 40-60 kg/s; head 0.5-0.7 MPa
- **Component Boundary**: Pump, transmission, motor, breaker, fuses, protection, controls
- **Operating Mode**: Running
- **Operating Environment**: Normal
- **Generic Failure Mode**: Fail to run
- **Original Failure Mode**: Spurious stop
- **Failure Rate or Probability (mean)**: 6.9E-5/hr
- **Repair Time**: 3 hr
- **Source**: Swedish Rel.data book, tbl.1
- **Comment**: Ultimate source: Plant operating experience, Ringhals 2 PWR
- **Operating Experience**: Total pop. 2. Operational time 4.32E+4 hours, 3 failures.

### PMQST
- **Pump Motor Driven Centrifugal**: Horizontal and vertical flow rate 120-240 kg/s; head 1.2-1.8 MPa
- **Component Boundary**: Pump, motor, transmission, switch, fuses, protection, controls
- **Operating Mode**: Standby
- **Operating Environment**: Normal
- **Generic Failure Mode**: Fail to start
- **Original Failure Mode**: Failure to start
- **Failure Rate or Probability (mean)**: 5.1E-3/d
- **95%**: 2.1E-2/d
- **Repair Time**: 3 hr
- **Source**: Swedish Rel.data book, tbl.8
- **Comment**: Ultimate source: Plant operating experience (7 BWR plants), ATV reports, LERs
- **Operating Experience**: Total pop. 18. No. of demands 784, 4 failures. a=0.387; b=75.4 Critical failures occurred at 2 plants.

### PMHRH
- **Pump Motor Driven Charging Pump

- **Component Boundary**: Detail n/a
- **Operating Mode**: Alternating
- **Operating Environment**: Normal
- **Generic Failure Mode**: Fail to run
- **Original Failure Mode**: Fail during operation
- **Failure Rate or Probability (mean)**: 2.7E-4/hr
- **95%**: 3.4E-4/hr
- **5%**: 2.0E-4/hr
- **Repair Time**: 16 hours
- **Source**: Old PWR
- **Comment**: Generic mean 3.4E-5/hr. Operating experience 1.3E+5 hours of operation, 38 failures. Repair time is mean of 168 recorded maintenance events (short single pump outage). Long outage = 667 hrs.

### PMHSH
- **Pump Motor Driven Charging Pump

- **Component Boundary**: Detail n/a
- **Operating Mode**: Alternating
- **Operating Environment**: Normal
- **Generic Failure Mode**: Fail to start
- **Original Failure Mode**: Fail to start on demand
- **Failure Rate or Probability (mean)**: 1.2E-3/d
- **95%**: 2.6E-3/d
- **5%**: 1.4E-4/d
- **Source**: Old PWR
- **Comment**: Generic mean 2.4E-3/d. Operating experience 559 demands, no failures.
PMHRA pump motor driven charging/high pressure injection
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail to run
FAILURE RATE OR PROBABILITY median: 5.5E-5/hr  ERROR FACTOR: 2.9
Source: NUREG 4550/Vol.3,tbl.IV.8-1  Ultimate source: Surry NPP operating experience
Comment: Charging pump provide RCS makeup and RPS seal cooling flow in normal operation and serve as a high pressure injection/recirculation pump following accident.

PMHSA pump motor driven charging/high pressure injection
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start
FAILURE RATE OR PROBABILITY median: 3.1E-3/d  ERROR FACTOR: 3.5
Source: NUREG 4550/Vol.3,tbl.IV.8-1  Ultimate source: Surry NPP operating experience
Comment: Charging pumps provide normal RCS makeup and RCP cooling flow in normal operation and serve as a high pressure injection/recirculation following accident.

PMERZ pump motor driven component cooling
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 1.8E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data upgraded with plant specific experience
Comment: Priors:NUREG 1205, alternating system, does not operate given start, (Mean) and WASH 1400 pump (w/o motor) failure to run (Distrib). Operating experience: 6.6E+4 hrs of operation, no failures.

PMCRH pump motor driven containment spray
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 3.4E-5/hr  95%: 7.8E-5/hr  5%: 2.8E-6/hr  REPAIR TIME: 6.6 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 209 hours of operation, no failures. Repair time is mean of 16 maintenance events.

PMCRZ pump motor driven containment spray
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 1.5E-5/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant specific experience
Comment: Priors:NUREG 1205, alternating system, does not operate given start (mean) and WASH 1400, pump (w/o motor), failure to run (distrib). Operating experience: 66 hours of operation, no failures.
PMCSH  pump motor driven containment spray
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 5.1E-3/d  95%: 9.0E-3/d  5%: 1.7E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 65% demands, 4 failures.

PMGSH  pump motor driven electric equipment area ventilation cooling pump
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 1.4E-3/d  95%: 3.2E-3/d  5%: 2.0E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 329 demands, no failures.

PMGRH  pump motor driven electrical equipment area ventilation cooling pump
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 4.7E-5/hr  95%: 7.4E-5/hr  5%: 2.2E-5/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 1.3E+5 hours of operation, 7 failures.

PMFRO  pump motor driven emergency feedwater pump
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 2.0E-5/hr  95%: 6.0E-5/hr  5%: 5.9E-7/hr  REPAIR TIME: 20.9 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: mean NUREG 1205(1980), alternating pump, 80%/20% based on RSS distribution. Same prior as injection pumps. Op. experience: 15 op. hrs, no failures. Repair time is mean generic maintenance duration.

PMFSD  pump motor driven emergency feedwater pump
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 4.8E-4/d  95%: 1.4E-3/d  5%: 1.4E-5/d  REPAIR TIME: 20.9 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
PMARJ pump motor driven general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: fails to run
FAILURE RATE OR PROBABILITY mean : 3.0E-5/hr ERROR FACTOR: 10
Source: NUREG 4550, Vol.1,tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: ASEP used the generic values developed in the Station Blackout Study (NUREG/C R 3226).

PMASJ pump motor driven general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: fails to start
FAILURE RATE OR PROBABILITY mean : 3.0E-3/d ERROR FACTOR: 10
Source: NUREG 4550, Vol.1,tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: ASEP used the generic values developed in the Station Blackout Study (NUREG/C R 3226). Value for fails to start included two types of failures: Pump hardware (4.0E-4/d) and circuit board command (2.5E-3).

PMISU pump motor driven high pressure (>20 bar) applicable to HHSI, CVCS and auxiliary feedwater pumps
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY mean : 4.0E-3/d
Source: Sizewell B (PWR/RX312 pg.9) Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data, WASH 1400, EDF data and 2 SRS data items one applies to HHSI, RHR and auxfeed (4.0E-3/d) and other to CVCS and CWCS (2.0E-3/d).

PMVRO pump motor driven high pressure injection
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to run Original failure mode: operational failure
FAILURE RATE OR PROBABILITY mean : 8.4E-6/hr 95%: 2.0E-5/hr 5%: 4.4E-7/hr REPAIR TIME: 21.5 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant-specific operating experience
Comment: Prior: Mean NUREG 1205 (1980), alternating pump, 80%/20% ratio based on RSS. Operating experience: 38,787 hours of operation, no failures. Repair time is mean of updated component maintenance duration.

PMVSO pump motor driven high pressure injection
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean : 8.4E-4/d 95%: 2.1E-3/d 5%: 6.0E-5/d REPAIR TIME: 21.5 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant-specific operating experience
Comment: Prior: Mean NUREG 1205 (1980), standby pump, 80%/20% ratio based on RSS distribution. Operating experience: 530 demands, 1 failure. Repair time is mean of updated component maintenance duration.
PMIRU  pump motor driven high pressure (> 20 bar) applicable to HHSI, CVCS and auxiliary feedwater pumps
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: failure to continue operation
FAILURE RATE OR PROBABILITY  mean : 6.0E-5/hr
Source: Sizewell B (PWR/RX312 pg.10)  Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assesement based on W data and 3 SRS data items. Two of them applies to RHR, HHSI and auxfeed (5.0E-5/hr and 1.0E-5/hr) and one to CVCS and CCWS (2.0E-5/hr).

PMZSD pump motor driven include CCW, SW, RHR, boric acid transfer, boron injection recirc.
Component boundary: pump, shaft, motor, switches, local control & instrumentation  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fails to start
FAILURE RATE OR PROBABILITY  mean : 5.3E-3/d  : 6.0E-4/d  : 5.0E-2/d
Comment: Pop.102. 22 catastrophic demand related failures of 4148 demand Upbound & lowbound are largest and smallest rate of funct.aggregation of the pumps class by driver type. Include altern. and standby pumps.

PMZRD pump motor driven include CCW, SW, RHR, boric acid transfer, boron injection recirc.
Component boundary: pump, shaft, motor, switches, local control and instrumentation  Operating mode: alternating  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fails while running
FAILURE RATE OR PROBABILITY  mean : 2.7E-5/hr  : 3.0E-4/hr  : 1.0E-6/hr
Source: NUREG 2886 (1982)(tbl.18 & 19)  Ultimate source: plant operating experience-maintenance records(2PWR & 4BWR)
Comment: Pop.102.33 catastrophic failures of 1.24E+6 population hours Upbound and lowbound identical as running pumps(see comment).

PMTSD pump motor driven include containment spray, standby liquid control
Component boundary: pump, shaft, motor, switches, local control and instrumentation  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fails to start
FAILURE RATE OR PROBABILITY  mean : 5.5E-3/d  : 6.0E-4/d  : 5.0E-2/d
Source: NUREG 2886 (1982)(tbl.18 & 19)  Ultimate source: plant operating experience-maintenance records(2PWR & 4BWR)
Comment: Pop.95.31 catastrophic demand related failures of 5456 demands Up & lowbound derived from funct.aggregation. Failrate is based on 1 demand/month. (actual 2-3 times higher) very conservative.

PMJRO pump motor driven includes reactor coolant, reactor recirculating, CW, feedwater, cond.
Component boundary: pump, shaft, motor, switches, local control & instrumentation  Operating mode: running  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fails while running
FAILURE RATE OR PROBABILITY  mean : 2.2E-5/hr  : 3.0E-4/hr  : 1.0E-6/hr
Source: NUREG 2886 (1982)(tbl.18 & 19)  Ultimate source: plant operating experience-maintenance records(2PWR & 4BWR)
Comment: Pop.79. 35 catastrophic time related failures of 1.6E+6 operating hours. Upbound and lowbound are the largest and smallest rate of funct.aggregation by driver.
PMCSA  pump motor driven inside spray recirculation

Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start/run

FAILURE RATE OR PROBABILITY  median: 3.6E-2/d  ERROR FACTOR: 1.8
Source: NUREG 4550/Vol.3,tbl.IV.8-1  Ultimate source: Surry NPP operating experience (test data)
Comment: It was not possible to identify failure mode in table. It seems to cover starting failure and initial running failure (during test)

PULRU  pump motor driven low pressure <20 bar applicable to ESWS, CCWS, LHSI/RHR, CSS, boric acid transfer pumps

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: failure to continue operation

FAILURE RATE OR PROBABILITY  mean: 1.5E-5/hr
Source: Sizewell B (PWR/RX312 pg.11)  Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data, EDF data items(1.2E-4/hr ESW pumps) (6.8E-6/hr CCW), (5.6E-6/hr cond.extraction), (3.5E-6/hr cond.cool.), 2 SRS items(industrial use)(2.1E-4/1E5hrs) and 1.8E-5/5E5hrs).

PULSU  pump motor driven low pressure <20 bar applicable to ESWS, CCWS, LHSI/RHR, CSS, boric acid transfer

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start

FAILURE RATE OR PROBABILITY  mean: 2.0E-3/d
Source: Sizewell B (PWR/RX312 pg.11)  Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data, WASH 1400, EDF data item (1.8E-4/d out of 16800 demands) and two SRS data items (4.0E-3/d for HHSI, RHR and auxfeed) and (2.0E-3/d for CVCS and CCWS).

PHLRO  pump motor driven low pressure injection

Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: operational failure

FAILURE RATE OR PROBABILITY  mean: 3.7E-5/hr  95%: 9.5E-5/hr  5%: 2.5E-6/hr  REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tbl.1-1)  Ultimate source: generic data updated with plant specific operational experience
Comment: Prior:mean NUREG 1205(1980), alternating pump, 80%/20% ratio based on RSS. Same prior as for HPI pump. Op.experience: 11.287 op.hrs, 1 failure. Repair time is mean of generic maintenance duration.

PMLSO  pump motor driven low pressure injection

Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start

FAILURE RATE OR PROBABILITY  mean: 3.7E-4/d  95%: 1.0E-3/d  5%: 1.4E-5/d  REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tbl.1-1)  Ultimate source: generic data updated with plant specific operational experience
Comment: Prior:mean NUREG 1205(1980), standby pump, 80%/20% ratio based on RSS dist. Same prior as for HPI pump. Op.exp. 223 demands, no fail. Repair time is mean generic component maintenance duration.
PMKRO pump motor driven low pressure service water
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to run Original failure mode: operational failure
FAILURE RATE OR PROBABILITY mean : 2.8E-5/hr 95%: 5.6E-5/hr 5%: 4.1E-6/hr REPAIR TIME: 10.5 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: mean NUREG 1205(1980), alternating pump, 80%/20% ratio based on RSS. Op. experience: 47,991 hours of operation, 2 failures. Repair time is mean of plant specific update of maintenance duration.

PMKSO pump motor driven low pressure service water
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start
FAILURE RATE OR PROBABILITY mean : 4.5E-4/d 95%: 1.3E-3/d 5%: 1.4E-5/d REPAIR TIME: 10.5 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience

PUMRU pump motor driven main feed pumps
Component boundary: detail n/a Operating mode: running Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail to continue operation
FAILURE RATE OR PROBABILITY mean : 8.0E-4/hr
Source: Sizewell B (PWR/4X312 pg.8) Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data, CEGB data item, EDF PWR data (3.1E-4/hr out of 4.2E+6 hrs) and 2 SRS data items (7.4E-4/hr and 1.7E-3/hr based on operating experience 2.5E+5 hr).

PURSH pump motor driven main steam relief hydraulic pump
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean : 6.9E-4/d 95%: 1.2E-3/d 5%: 2.6E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 5636 demands, 3 failures.

PUERH pump motor driven primary component cooling water pump
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 1.4E-5/hr 95%: 2.5E-5/hr 5%: 3.9E-6/hr REPAIR TIME: 8 hours
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 1.7E+5 hours of operation, 2 failures. Repair time is mean of 14 maintenance events.
PUESK  pump motor driven primary component cooling water pump  
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal  
Generic failure mode: fail to start  Original failure mode: fail to start on demand  
FAILURE RATE OR PROBABILITY  mean : 3.4E-3/d  95%: 5.2E-3/d  5%: 1.7E-3/d  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 2.4E-3/d. Operating experience 1840 demands, 7 failures.

PUBRH  pump motor driven primary service water booster pump  
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal  
Generic failure mode: fail to run  Original failure mode: fail during operation  
FAILURE RATE OR PROBABILITY  mean : 6.4E-5/hr  95%: 1.0E-5/hr  5%: 2.8E-5/hr  REPAIR TIME: 12.1  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 3.4E-5/hr. Operating experience 9.2E+4 hours of operation, 7 failures. Repair time is mean of 17 maintenance events.

PUBSH  pump motor driven primary service water booster pump  
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal  
Generic failure mode: fail to start  Original failure mode: fail to start on demand  
FAILURE RATE OR PROBABILITY  mean : 1.6E-3/d  95%: 3.7E-3/d  5%: 2.2E-4/d  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 2.4E-3/d. Operating experience 222 demands, no failures.

PUKRU  pump motor driven primary service water pump  
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal  
Generic failure mode: fail to run  Original failure mode: fails during operation  
FAILURE RATE OR PROBABILITY  mean : 5.5E-5/hr  95%: 9.2E-5/hr  5%: 2.7E-5/hr  REPAIR TIME: 17.4 hours  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 3.4E-5/hr. Operating experience 1.6E+5 hours of operation, 10 failures. Repair time is mean of 46 maintenance events.

PUKSU  pump motor driven primary service water pump  
Component boundary: detail n/a  Operating mode: alternating  Operating environment: normal  
Generic failure mode: fail to start  Original failure mode: fail to start on demand  
FAILURE RATE OR PROBABILITY  mean : 1.3E-3/d  95%: 2.3E-3/d  5%: 3.9E-4/d  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 2.4E-3/d. Operating experience 1909 demands, 2 failures.
**PMCSO** pump motor driven reactor building spray
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY  mean : 8.1E-3/d  95%: 1.8E-2/d  5%: 1.1E-3/d  
REPAIR TIME: 28.6 hours
Source: Swedish Rel.data book, tbl.10  Ultimate source: plant operating experience (7 BWR plants)
Comment: Operating experience:total pop 22. No.of demands 1238. 5 failures a=0.186; b=46. Critical failures occured at 3 plants.

**PUZRH** pump motor driven recirculation pump
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 3.4E-5/hr  95%: 8.1E-5/hr  5%: 2.8E-6/hr  
REPAIR TIME: 4.2 hours
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr  Operating experience 56 hours of operation, no failures. Repair time is mean of 14 maintenance events.

**PUZSR** pump motor driven recirculation pump
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 3.3E-3/d  95%: 2.5E-3/d  5%: 1.3E-4/d  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 684 demands, no failures.
**PUWRH** pump motor driven residual heat removal pump
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal
Generic failure mode: fail to run  
Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 1.1E-4/hr  
95%: 2.4E-4/hr  
5%: 2.5E-5/hr  
REPAIR TIME: 4.8 hours
Source: Old PWR  
Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 1.4E+4 hours of operation, 3 failures. Repair time is mean of 2 maintenance events (short duration). Long duration maintenance 6.1E+3 hours??

**PUWRZ** pump motor driven residual heat removal pump
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal
Generic failure mode: fail to run  
Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 2.5E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  
Ultimate source: generic data updated with plant specific experience
Comment: Priors:NUREG 1205 alternating system,does not operate given start (mean) and WASH 1400,pump (w/o motor),fail to run(distrib.). Operating experience: 3.25E+4 hrs of operation, no failures.

**PUWSH** pump motor driven residual heat removal pump
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal
Generic failure mode: fail to start  
Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean: 6.5E-3/d  
95%: 1.7E-2/d  
5%: 7.1E-4/d
Source: Old PWR  
Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 58 demands, 1 failure

**PMSRH** pump motor driven safety injection pump
Component boundary: detail n/a  
Operating mode: standby  
Operating environment: normal
Generic failure mode: fail to run  
Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 3.6E-5/hr  
95%: 7.8E-5/hr  
5%: 2.8E-6/hr  
REPAIR TIME: 4.8 hours
Source: Old PWR  
Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 272 hours of operation, no failures. Repair time is mean of 21 recorded maintenance events.

**PMSRZ** pump motor driven safety injection pump
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal
Generic failure mode: fail to run  
Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 1.6E-5/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  
Ultimate source: generic data updated with plant specific experience
Comment: Prior: NUREG 1205, alternating system, does not operate given start (M) and WASH 1400, pump (w/o motor), fail to run (distrib.). Operating experience: 46 hours of operation, no failures.
**PMSSH**  
Pump motor driven safety injection pump  
Component boundary: detail n/a  
Operating mode: standby  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: fail to start on demand  
FAILURE RATE OR PROBABILITY  
mean: 8.4E-3/d  
95%: 1.3E-2/d  
5%: 3.7E-3/d  
Source: Old PWR  
Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 3.3E-3/d. Operating experience 719 demands, 7 failures.

**PUSRY**  
Pump motor driven screw flow rate  
Component boundary: Pump, transmission, motor, breaker, fuse, protection, control  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: spurious stop  
FAILURE RATE OR PROBABILITY  
mean: 3.1E-5/hr  
REPAIR TIME: 32 hr  
Source: Swedish Rel.data book, tbl.6  
Ultimate source: plant operating experience Ringhals 2 PWR  
Comment: Operating experience: total pop. 6 Operating time 12.97E+4 hours 4 failures.  
No failure to start recorded on this component.

**PUSST**  
Pump motor driven screw flow rate  
Component boundary: Pump, transmission, motor, switch, fuses, protection, control  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: failure to start  
FAILURE RATE OR PROBABILITY  
mean: 2.5E-3/d  
95%: 1.4E-2/d  
REPAIR TIME: 8 hours  
Source: Swedish Rel.data book, tbl.6  
Ultimate source: plant operating experience (1 BWR plant), ATV reports, LERs  
Comment: Operating experience: total pop. 7 No. of demands 399. 1 failure. a=0.164; b=65.2

**PUFRH**  
Pump motor driven secondary component cooling water  
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to run  
Original failure mode: fail during operation  
FAILURE RATE OR PROBABILITY  
mean: 7.3E-6/hr  
95%: 1.6E-5/hr  
5%: 1.3E-6/hr  
REPAIR TIME: 73.8 hours  
Source: Old PWR  
Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 3.4E-5/hr. Operating experience 1.4E+5 hours of operation, no failures. Repair time is mean of 7 maintenance events.

**PUFSH**  
Pump motor driven secondary component cooling water  
Component boundary: detail n/a  
Operating mode: alternating  
Operating environment: normal  
Generic failure mode: fail to start  
Original failure mode: fail to start on demand  
FAILURE RATE OR PROBABILITY  
mean: 1.7E-3/d  
95%: 3.9E-3/d  
5%: 2.3E-4/d  
Source: Old PWR  
Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 2.4E-3/d. Operating experience 193 demands, no failures.
PMKRH pump motor driven secondary service water
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 5.5E-5/hr 95%: 8.6E-5/hr 5%: 2.5E-5/hr REPAIR TIME: 32.5 hours
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 1.4E+5 hours of operation, 9 failures. Repair time is mean of 17 maintenance evens.

PMKSH pump motor driven secondary service water pump
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY mean: 1.7E-3/d 95%: 3.8E-3/d 5%: 2.3E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 203 demands, no failures.

PMKRZ pump motor driven service water
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 1.3E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
Comment: Priors:NUREG 1205,alternating system,does not operate given start (mean) and WASH 1400, pump(w/o motor),failure to run(distrib). Operating experience:1.52E+5 hours of operation,no failures.

PUCRA pump motor driven service water pump used in charging pump cooling system
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail to run
FAILURE RATE OR PROBABILITY median: 1.6E-4/hr ERROR FACTOR: 1.6
Source: NUREG 4550/Vol 3,tbl.IV.8-1 Ultimate source: Surry NPP operating experience
Comment:

PUCSA pump motor driven service water pump used in charging pump cooling system
Component boundary: detail n/a Operating mode: alternating Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start
FAILURE RATE OR PROBABILITY median: 5.9E-3/d ERROR FACTOR: 3.5
Source: NUREG 4550/Vol 3,tbl.IV.8-1 Ultimate source: Surry NPP operating expereince
Comment:
puVRH  pump motor driven well water pump
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY  mean : 3.4E-5/hr  95%: 8.0E-5/hr  5%: 2.8E-6/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.4E-5/hr. Operating experience 108 hours, no failures.

puVSH  pump motor driven well water pump
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fail to start on demand
FAILURE RATE OR PROBABILITY  mean : 3.7E-3/d  95%: 8.4E-3/d  5%: 5.3E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-3/d. Operating experience 192 demands, 1 failure.

pTAFP  pump turbine driven
Component boundary: incl.mech.contol,governor,trip-throt.vlv,lube oil sys,bearing lb  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: does not operate
FAILURE RATE OR PROBABILITY  median: 2.1E-2/d  95%: 2.3E-2/d  5%: 1.8E-2/d
Comment: Overall data, includes all types of reactors, LER 72-80. Ttl.pop. 92. W/o command faults. With command faults 5.0E-2. Fail mode include fail to start, leak/rupt, loss of function, does not cont. to run

pTASD  pump turbine driven
Component boundary: pump,shaft,turbine,local instrumentaion and control  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: fails to start
FAILURE RATE OR PROBABILITY  mean : 1.1E-2/d  3.0E-2/d  2.0E-3/d
Comment: Pop.11. 5 catastrophic demand related failures in 469 demands. Upbound and lowbound are the largest and smallest failure rate of the functional aggregate of selected pumps classified by driver

pTASP  pump turbine driven
Component boundary: incl.mech.control,governor,trip-throt.vlv,lube oil sys,bearing lb  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: does not start
FAILURE RATE OR PROBABILITY  median: 9.6E-3/d  95%: 1.2E-2/d  5%: 8.0E-3/d
Comment: Overall data, including all types of reactors, LER 72-80. Ttl.pop. 92. W/o command faults. With command faults 2.5E-2. Standby hour rate w/o command 1.9E-5/hr, with command faults 5.1E-5/hr.
**PTRRD** pump turbine driven
Component boundary: pump, shaft, turbine, local control and instrumentation Operating mode: running Operating environment: normal
Generic failure mode: fail to run Original failure mode: fails while running
FAILURE RATE OR PROBABILITY mean: 1.0E-4/hr max: 2.0E-4/hr min: 8.0E-5/hr
Comment: Pop.11.21 catastrophic time related failures in 2.0E-5 op.hours. Upbound and low bound are the largest and smallest rate of the functional aggregates of the selected pumps classified by driver

**PTYRB** pump turbine driven
Component boundary: pump, turbine, steam and throttle valve, governor Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run given start
FAILURE RATE OR PROBABILITY mean: 2.0E-5/hr max: 1.0E-4/hr min: 8.0E-6/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion aggregation and IREP data
Comment:

**PTYRI** pump turbine driven
Component boundary: pump, turbine, steam and throttle valves, governor Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: failure to run given start
FAILURE RATE OR PROBABILITY mean: 1.0E-5/hr ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

**PTYSB** pump turbine driven
Component boundary: pump, turbine, steam and throttle valves, governor Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean: 1.0E-4/hr max: 5.0E-4/hr min: 2.0E-6/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion aggregation and IREP data
Comment: Failure mode includes under and over speed

**PTYSI** pump turbine driven
Component boundary: pump, turbine, steam and throttle valves, governor Operating mode: all Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean: 3.0E-2/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: Failure mode includes under and overspeed
PTFRZ pump turbine driven auxiliary feedwater
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to run Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 7.6E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
Comment: Prior: NUREG 1205 ("turbine driven pump failure during operation is similar to motor driven.
Operating experience: 1900 hours of operation, no failures.

PTFSA pump turbine driven auxiliary feedwater
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start/run
FAILURE RATE OR PROBABILITY median: 7.1E-3/d ERROR FACTOR: 4.6
Source: NUREG 4550/Vol.3, tbl.IV.8-1 Ultimate source: Surry NPP operating experience
Comment: It was not possible to identify failure mode as appear in table.

PTFSZ pump turbine driven auxiliary feedwater
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: failure to start on demand
FAILURE RATE OR PROBABILITY mean: 2.3E-2/d
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
Comment: Prior: NUREG 1205, standby system (w/o command) does not start (Mean) Distribution based on engineering judgement.
Operating experience: 231 demands, 6 failures.

PTCSY pump turbine driven centrifugal pump flow rate 240 kg/s; head 1.8 MPa
Component boundary: auxiliary equipment not included Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start
FAILURE RATE OR PROBABILITY mean: 3.3E-2/d REPAIR TIME: 8 hr
Source: Swedish Rel. data book, tbl.9 Ultimate source: plant operating experience Ringhals 2 PWR
Comment: One observed component, 30 demands per operational time, one failure recorded.

PTXSO pump turbine driven emergency feedwater
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to start Original failure mode: fail to start
FAILURE RATE OR PROBABILITY mean: 3.8E-2/d 95%: 5.8E-2/d 5%: 1.2E-2/d REPAIR TIME: 24.5 hours
Source: Oconee NPP PRA (tbl.b.1.) Ultimate source: generic data updated with plant specific operating experience
Repair time is mean of plant spec. update of maintenance duration.
PTXRO  pump turbine driven emergency feedwater pump
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY mean : 9.9E-4/hr  95%: 4.0E-3/hr  5%: 4.1E-6/hr  REPAIR TIME: 24.5 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:mean NUREG 1205(1980), alternating pump.80%/20% ratio =100  Operating experience:94 hours of operation,1 failure.
Repair time is mean of plant spec.update of maintenance duration.

PTARJ  pump turbine driven general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fails to run
FAILURE RATE OR PROBABILITY mean : 5.0E-3/hr  ERROR FACTOR: 10
Source: NUREG 4550, Vol.1,tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: ASEP value is taken from IREP Procedure Guide.

PTASJ  pump turbine driven general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: fails to run
FAILURE RATE OR PROBABILITY mean : 3.0E-2/d  ERROR FACTOR: 10
Source: NUREG 4550, Vol.1,tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: ASEP used generic value from IREP Procedure Guide. The value for fails to start incl. two types of failures: circuit breaker command faults(2.0E-2) and pump hardware(1.0E-2).

PTSRU  pump turbine driven high pressure > 20 bar include CVCS,emergency charging system,aux.feedwater pumps
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to run  Original failure mode: failure to continue operation
FAILURE RATE OR PROBABILITY mean : 6.0E-5/hr
Source: Sizewell B (PWR/RX312 pg.12)  Ultimate source: assessed from nuclear and industrial experience
Comment: Assessment based on W data and SRS data item relevant for PWR (5.0E-5/hr).

PTSSU  pump turbine driven high pressure > 20 bar include CVCS,emergency charging system and aux.feedwater pumps
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to start  Original failure mode: failure to start
FAILURE RATE OR PROBABILITY mean : 2.0E-2/d
Source: Sizewell B (PWR/RX312 pg.12)  Ultimate source: assessed from nuclear and industrial experience and data
Comment: Assessment based on W data and SRS data item relevant for PWR (1.0E-2/d).
PDARJ pump diesel driven generator
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to run Original failure mode: fails to run
FAILURE RATE OR PROBABILITY mean: 8.0E-4/hr ERROR FACTOR: 10
Source: NUREG 4550, Vol.1,tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: ASEP used generic values from LERs.

ARBBM radiation monitors BWR main steam line
Component boundary: radiation channel Operating mode: operating Operating environment: normal
Generic failure mode: degraded Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean: 9.6E-6/hr 95%: 1.2E-5/hr 5%: 7.4E-6/hr
Comment: BWR rate with command faults. W/o command faults 9.1E-6/hr.

ARBFM radiation monitors BWR main steam line
Component boundary: radiation channel Operating mode: operating Operating environment: normal
Generic failure mode: fail to function Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 6.0E-6/hr 95%: 8.4E-6/hr 5%: 4.3E-6/hr
Comment: BWR rate with command faults. W/o command faults 5.6E-6/hr.

URSFI reactor scram system
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to scram
FAILURE RATE OR PROBABILITY mean: 3.0E-5/d ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert judgement
Comment:

EREFE rectifier excitation rectifier over 600 V
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output(catastrophic)
FAILURE RATE OR PROBABILITY rec: 1.3E-6/hr high: 3.6E-6/hr low: 3.2E-7/hr
Source: IEEE 500 (1984) pg.421 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure node "no output" consist of: 1) automatic removal by protective circuitry; 2) manual removal; 3) open circuit
ERPFE  rectifier precipitator rectifier over 600 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec.: 1.4E-6/hr  high: 4.1E-6/hr  low: 3.6E-7/hr
Source: IEEE 500 (1984) pg.422  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode "no output" consist of: 1) automatic removal by protective circuitry; 2) manual removal; 3) open circuit.

ERSFT  rectifier static
Component boundary: rectifier, fuse(380V side), tap.  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: loss of effective output
FAILURE RATE OR PROBABILITY  mean: 1.4E-6/hr  95%: 5.8E-6/hr  REPAIR TIME: 16 hours
Source: Swedish Rel.data book, tbl.42  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
No. of failures 6. a=0.0324; b=23000 Critical failures at 3 plants

RAADE  relay auxiliary all types
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY  high: n/a  : 1.5E-5/cy
Source: IEEE 500 (1984) pg.195  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of different voltage levels of switchgear auxiliary relays.

RAAEE  relay auxiliary all types
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY  high: n/a  : 7.0E-6/cy
Source: IEEE 500 (1984) pg.195  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of different voltage levels of switchgear auxiliary relays

RAAEO  relay auxiliary all types
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open
FAILURE RATE OR PROBABILITY  high: n/a  : 8.9E-6/cy
Source: IEEE 500 (1984) pg.195  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of different voltage levels of switchgear auxiliary relays
RCAE relay control AC control relay
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 3.0E-7/hr high: 4.3E-4/hr low: 4.0E-8/hr
Source: IEEE 500 (1984) pg.186 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of 4 AC control relays voltage levels.

RCDAE relay control DC control relay
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 3.6E-7/hr high: 2.1E-4/hr low: 2.0E-8/hr
Source: IEEE 500 (1984) pg.191 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of 3 DC control relays voltage levels.

RCLDE relay control all types
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY rec : 4.0E-8/hr high: 2.5E-4/hr low: 1.0E-8/hr
Source: IEEE 500 (1984) pg.183 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of AC and DC control relays and different voltage levels in both groups. Reference IEEE 500(1977)

RCLEE relay control all types
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close
FAILURE RATE OR PROBABILITY rec : 3.9E-6/cy high: 5.6E-6/cy low: 0.0E-0/cy
Source: IEEE 500 (1984) pg.183 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of AC and DC control relays and different voltage levels in both groups.

RCLOE relay control all types
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY rec : 3.1E-6/cy high: 4.6E-6/cy low: 0.0E-0/cy
Source: IEEE 500 (1984) pg.183 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of AC and DC control relays and different voltage levels in both groups. Reference IEEE 500(1977)
RCEAF relay control electromechanical
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 3.4E-7/hr  95%: 4.2E-7/hr  5%: 2.7E-7/hr  ERROR FACTOR: 1.2  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative operating time 172.2E+6 hours. 59 failures. Repair time is conservatively estimated to be 3 hours.

RCECF relay control electromechanical
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to energise
FAILURE RATE OR PROBABILITY mean: 1.0E-4/d  95%: 3.0E-4/d  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

RCEEF relay control electromechanical
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure of NO contacts to close when energised
FAILURE RATE OR PROBABILITY mean: 3.4E-7/hr  95%: 1.0E-6/hr  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Data based on 48 V DC relays commonly used in control circuits. Ultimate source is not known (op. exper. or expert). No. of demands in time is not known. Same failure rate for "NC contacts to open".

RCEOF relay control electromechanical
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure of NO contacts to open when de-energised
FAILURE RATE OR PROBABILITY mean: 1.0E-7/hr  95%: 3.4E-7/hr  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Data based on 48 V DC relays used in control circuits. Ultimate data source not known (op. exper. or expert). No of demands in time is not known. Same failure rate for "NC to close".

RWAFW relay general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to energize
FAILURE RATE OR PROBABILITY median: 1.0E-4/d  95%: 3.0E-4/d  5%: 3.0E-5/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Due to available data, failure rates of "failure to energise" include failure of normaly open contacts to close. Generally, relay and contacts failure rates should not be combined together.
RWCW relay general
Component boundary: detail n/a Operating mode: normally closed Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: failure of NC contacts by opening, given not energised
FAILURE RATE OR PROBABILITY median: 1.0E-7/hr 95%: 3.0E-7/hr 5%: 3.0E-8/hr ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear experience
Comment:

RWOEW relay general
Component boundary: detail n/a Operating mode: normally open Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure of NO contacts to close, given energised
FAILURE RATE OR PROBABILITY median: 3.0E-7/hr 95%: 1.0E-6/hr 5%: 1.0E-7/hr ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Available data do not completely separate causes of failures, so failure modes are not necessarily independent. Fail to energise includes this failure mode. Relay & contacts rates should not be added.

RPHFG relay power 300-460 A
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: loss of main function
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr ERROR FACTOR: 15
Source: German Risk Study (tb.F3,7-1) Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources

RPLFG relay power 40-60 A
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: loss of main function
FAILURE RATE OR PROBABILITY median: 9.0E-7/hr ERROR FACTOR: 10
Source: German Risk Study (tb.F3,7-1) Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources.

RRADE relay protective all types
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY rec : 3.0E-8/hr high: 2.4E-4/hr low: 0.0 REPAIR TIME: .55 hours
Source: IEEE 500 (1984) pg.164 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of all types and voltage levels of protective relays. References IEEE 500 (1977) and IEEE 493 (1980)
RRAEE relay protective all types
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fails to close
FAILURE RATE OR PROBABILITY rec : 3.0E-6/cy  high: 6.0E-6/cy  low: 8.5E-7/cy  REPAIR TIME: .55 hours
Source: IEEE 500 (1984) pg.164  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of all types and voltage levels of protective relays.

RRAOE relay protective all types
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open
FAILURE RATE OR PROBABILITY rec : 5.3E-7/cy  high: 1.1E-6/cy  low: 1.2E-7/cy  REPAIR TIME: .55 hours
Source: IEEE 500 (1984) pg.164  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of all types and voltage levels of protective relays. References IEEE 500 (1977) and IEEE 493(1980)

RROAE relay protective overload protection
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 7.3E-7/hr  high: 1.8E-6/hr  low: 1.1E-7/hr  REPAIR TIME: .5 hours
Source: IEEE 500 (1984) pg.168  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of current and temperature protection relays

RRSAE relay protective switchgear protection
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 2.5E-7/hr  high: 6.0E-4/hr  low: 1.0E-8/hr  REPAIR TIME: 61 hours
Source: IEEE 500 (1984) pg.179  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of two AC voltage level and one DC voltage level

RRVAE relay protective voltage protection
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 9.9E-7/hr  high: 2.2E-6/hr  low: 5.5E-7/hr  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.172  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of over and undervoltage protective relays.
**RTAAF**

**relay time delay**

- Component boundary: detail n/a
- Operating mode: all
- Operating environment: normal

**Generic failure mode:** all modes
**Original failure mode:** all modes

<table>
<thead>
<tr>
<th>FAILURE RATE OR PROBABILITY</th>
<th>mean</th>
<th>95%</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.9E-6/hr</td>
<td>2.9E-6/hr</td>
<td>1.4E-6/hr</td>
<td></td>
</tr>
</tbody>
</table>

**REPAIR TIME:** 3 hours

**Source:** HWR data
**Ultimate source:** HWR operating experience

**Comment:** Population not known. Cumulative operating time 9.2E+6 hours. 18 failures. Repair time is conservatively estimated to be 3 hrs.

---

**RTBCB**

**relay time delay bimetallic**

- Component boundary: detail n/a
- Operating mode: all
- Operating environment: normal

**Generic failure mode:** fail to change position
**Original failure mode:** fails to transfer

<table>
<thead>
<tr>
<th>FAILURE RATE OR PROBABILITY</th>
<th>mean</th>
<th>max</th>
<th>min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0E-5/hr</td>
<td>1.0E-5/hr</td>
<td>2.0E-7/hr</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** NUREG 2815 (table C.1.)
**Ultimate source:** expert judgement and IREP data

**Comment:**

---

**RTBCI**

**relay time delay bimetallic**

- Component boundary: detail n/a
- Operating mode: all
- Operating environment: normal

**Generic failure mode:** fail to change position
**Original failure mode:** fails to transfer

<table>
<thead>
<tr>
<th>FAILURE RATE OR PROBABILITY</th>
<th>mean</th>
<th>max</th>
<th>min</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0E-6/hr</td>
<td>5.0E-6/hr</td>
<td>2.0E-8/hr</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** IREP NUREG 2728 (tb.5.1-1) 
**Ultimate source:** expert opinion and non nuclear experience

**Comment:** Data source is MIL-HDBK 217B. Fail to transfer rates are not available for non-bimetallic time delay relays.

---

**RTADB**

**relay time delay general**

- Component boundary: detail n/a
- Operating mode: all
- Operating environment: normal

**Generic failure mode:** fail to remain in position
**Original failure mode:** premature transfer

<table>
<thead>
<tr>
<th>FAILURE RATE OR PROBABILITY</th>
<th>mean</th>
<th>max</th>
<th>min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0E-6/hr</td>
<td>5.0E-6/hr</td>
<td>2.0E-8/hr</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** NUREG 2815 (table C.1.)
**Ultimate source:** expert judgement and IREP data

**Comment:**

---

**RTADI**

**relay time delay general**

- Component boundary: detail n/a
- Operating mode: all
- Operating environment: normal

**Generic failure mode:** fail to remain in position
**Original failure mode:** premature transfer

<table>
<thead>
<tr>
<th>FAILURE RATE OR PROBABILITY</th>
<th>mean</th>
<th>ERROR FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0E-4/d</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** IREP NUREG 2728 (tb.5.1-1) 
**Ultimate source:** expert opinion

**Comment:**
**RTPAE** relay time delay pneumatic

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: all modes  
Original failure mode: all modes

**FAILURE RATE OR PROBABILITY**  
rec : 3.9E-7/hr  
high: 6.0E-4/hr  
low: 1.0E-8/hr

Source: IEEE 500 (1984) pg.206  
Ultimate source: expert opinion aggregation and operating experience

Comment: Given value is composite of AC and DC category of time delay pneumatic relays.

**RTSAE** relay time delay solid state

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: all modes  
Original failure mode: all modes

**FAILURE RATE OR PROBABILITY**  
rec : 1.6E-6/hr  
high: 1.0E-3/hr  
low: 1.0E-8/hr

Source: IEEE 500 (1984) pg.201  
Ultimate source: expert opinion aggregation and operating experience

Comment: Given value is composite of AC relay voltage levels and 1 DC relay voltage category.

**RYAFB** relay coil

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: fail to function  
Original failure mode: failed open or short

**FAILURE RATE OR PROBABILITY**  
mean : 3.0E-6/hr  
max: 2.0E-5/hr  
min: 6.0E-8/hr

Source: NUREG 2815 (table C.1.)  
Ultimate source: expert judgement and IREP data

Comment:

**RYAFI** relay coil

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: fail to function  
Original failure mode: failed open or short

**FAILURE RATE OR PROBABILITY**  
mean : 1.0E-6/hr  
ERROR FACTOR: 10

Source: IREP NUREG 2728 (tb.5.1-1)  
Ultimate source: expert opinion

Comment:

**RYAHF** relay coil

Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal

Generic failure mode: short circuit  
Original failure mode: short circuit

**FAILURE RATE OR PROBABILITY**  
mean : 1.0E-8/hr  
95%: 1.0E-7/hr  
REPAIR TIME: 3 hours

Source: HWR data  
Ultimate source: HWR assessment

Comment: Data based on 48 V DC relays used in control circuits. Ultimate data source (operating experience or expert) not known.
RYAHW relay coil
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: short circuit Original failure mode: short to power
FAILURE RATE OR PROBABILITY median: 1.0E-8/hr 95%: 1.0E-7/hr 5%: 1.0E-9/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2) Ultimate source: ultimate data source not known
Comment:

RYAIF relay coil
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: open circuit Original failure mode: open circuit
FAILURE RATE OR PROBABILITY mean: 1.0E-7/hr 95%: 1.0E-6/hr REPAIR TIME: 3 hours
Source: HWR data Ultimate source: HWR assessment
Comment: Data based on 48 V DC relays used in control circuits Ultimate data source (operating experience or expert) is not known.

RYAIW relay coil
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: open circuit Original failure mode: coil open
FAILURE RATE OR PROBABILITY median: 1.0E-7/hr 95%: 1.0E-6/hr 5%: 1.0E-8/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2) Ultimate source: ultimate data source not known
Comment:

RXAHF relay contacts
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: short circuit Original failure mode: short circuted
FAILURE RATE OR PROBABILITY mean: 1.0E-8/hr 95%: 1.0E-7/hr REPAIR TIME: 3 hours
Source: HWR data Ultimate source: HWR assessment
Comment: Data based on 48V DC relays used in control circuits. Ultimate data source (operating experience or expert opinion) is not known.

RXACB relay contacts general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to transfer
FAILURE RATE OR PROBABILITY mean: 1.0E-6/hr max: 5.0E-6/hr min: 2.0E-8/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert judgement and IREP data
Comment:
RXACI relay contacts general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to transfer
FAILURE RATE OR PROBABILITY  mean: 3.0E-4/d  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: failure mode include failure to transfer open or close

RXAHW relay contacts general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short across NO/NC contact
FAILURE RATE OR PROBABILITY  median: 1.0E-8/hr  95%: 1.0E-7/hr  5%: 1.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed form nuclear and military experience and data

ACABM sensor core flux general
Component boundary: sensor only  Operating mode: operating  Operating environment: normal
Generic failure mode: degraded  Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY  mean: 1.6E-7/hr  95%: 2.1E-7/hr  5%: 1.1E-7/hr
Comment: Overall rate, with command faults. W/o command faults 1.4E-7/hr. PWR rate is 6 times higher than BWR.

ACAFM sensor core flux general
Component boundary: sensor only  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: inoperable
FAILURE RATE OR PROBABILITY  mean: 2.9E-7/hr  95%: 3.5E-7/hr  5%: 2.2E-7/hr
Comment: Overall rate(BWR + PWR) with command faults. W/o command faults 2.5E-7/hr. PWR rate is order of magnitude higher.

AFAFT sensor flow general
Component boundary: sensor only (not clear)  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to function
FAILURE RATE OR PROBABILITY  mean: 3.3E-3/d  95%: 7.6E-3/d  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.32  Ultimate source: plant operating experience (3 BWR plants), ATV reports, LERs
Comment: Operating experience:total pop 34. No.of demands 990. No.of failures 1.a=0.0192; b=5.83
Critical failures reported at one plant.
AFAKT sensor flow general
Component boundary: not clear  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious function
FAILURE RATE OR PROBABILITY  mean: 4.3E-6/hr  95%: 2.3E-5/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.32  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 134. Operational time 500E+4 hours  No. of failures 22. a=0.18; b=41900
Critical failures reported on 4 plants.

AFAKT sensor flow general
Component boundary: sensor only  Operating mode: all  Operating environment: normal
Generic failure mode: other critical faults  Original failure mode: other critical faults
FAILURE RATE OR PROBABILITY  mean: 4.0E-7/hr  95%: 4.9E-7/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.32  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 134. Operational time 500E+4 hours  No. of failures 2. a=0.0148; b=37000
Critical failures reported on 2 plants.

ALAFT sensor level general
Component boundary: sensor only  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to function
FAILURE RATE OR PROBABILITY  mean: 2.1E-4/d  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.34  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 552. No. of demands 38.904. No. of failures 4. a=0.00191; b=9.24
Critical failures reported on 3 plants.

ALAKT sensor level general
Component boundary: sensor only  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious function
FAILURE RATE OR PROBABILITY  mean: 8.2E-7/hr  95%: 4.6E-6/hr  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.34  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 478. Operational time 1500E+4 hours  No. of failures 13. a=0.0648; b=79400.
Critical failures reported on 4 plants.

ALAXT sensor level general
Component boundary: sensor only  Operating mode: all  Operating environment: normal
Generic failure mode: other critical faults  Original failure mode: other critical faults
FAILURE RATE OR PROBABILITY  mean: 6.7E-7/hr  95%: 1.6E-6/hr  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.34  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 571. Operational time 1940E+4 hours  No. of failures 13. a=0.0205; b=30600
Critical failures reported on 5 plants.
ALRFS  sensor level reactor water level
Component boundary: detail n/a  Operating mode: all  Operating environment: reactor
Generic failure mode: fail to function  Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY  mean : 3.9E-6/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

APAFT  sensor pressure general
Component boundary: pressure sensor, excluding valves, piping etc.  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to function
FAILURE RATE OR PROBABILITY  mean : 7.0E-4/d  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.28  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 294. No. of demands 14,305, no. of failures 6. a=0.0124; b=17.8
Critical failures reported by 4 plants.

APAKT  sensor pressure general
Component boundary: pressure sensor only, excluding piping, valves etc.  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious function
FAILURE RATE OR PROBABILITY  mean : 8.7E-7/hr  95%: 2.2E-6/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.28  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 720. Operational time: 2750E+4 hours no. of failures 24. a=0.0215; b=24600

APAKY  sensor pressure general
Component boundary: pressure sensor only, excluding piping, valves etc.  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious function
FAILURE RATE OR PROBABILITY  mean : 8.8E-7/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.28  Ultimate source: plant operating experience (1 PWR plant, Ringhals 2)
Comment: Operating experience: total pop. 34. Operational time: 113.1E+4 hours 1 failure recorded.

APAXT  sensor pressure general
Component boundary: pressure sensor only, excluding piping, valves etc.  Operating mode: all  Operating environment: normal
Generic failure mode: other critical faults  Original failure mode: other critical faults
FAILURE RATE OR PROBABILITY  mean : 1.8E-7/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.28  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 720. Operational time: 2750E+4 hours no. of failures 5. a=0.00595; b=32700
Critical failures reported by 3 plants.
APAXY sensor pressure general
Component boundary: pressure sensor only, excluding piping, valves etc. Operating mode: all Operating environment: normal
Generic failure mode: other critical faults Original failure mode: other critical faults
FAILURE RATE OR PROBABILITY mean: 8.8E-7/hr REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.28 Ultimate source: plant operating experience (1 PWR plant-Ringhals 2)
Comment: Operating experience: total pop. 34. Operational time 113.1E+4 hours 1 failure recorded.

APRFS sensor pressure reactor and containment sensor
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY mean: 1.1E-6/hr
Source: Shoreham PRA, GE data (tb.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment: In the failure rate data comparison (table A.2-1), under this component category and failure mode, pressure switch failure to operate from WASH 1400 is included.

APDFT sensor pressure difference general
Component boundary: pressure difference sensor, excluding all piping, valves etc. Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail to function
FAILURE RATE OR PROBABILITY mean: 5.1E-3/d 95%: 2.6E-2/d REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.30 Ultimate source: plant operating experience (2 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 4. No. of demands 198. No. of failures 1. a=0.216; b=42.6
Critical failures reported on one plant only.

APDKT sensor pressure difference general
Component boundary: pressure difference sensor, excluding all piping, valves etc. Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: spurious function
FAILURE RATE OR PROBABILITY mean: 3.2E-7/hr REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.30 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 206. Operational time 313.1E+4 hours 1 failure. a=0.00467; b=14600
Critical failure reported on one plant.

APDKY sensor pressure difference general
Component boundary: pressure difference sensor, excluding all piping, valves etc. Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: spurious function
FAILURE RATE OR PROBABILITY mean: 2.5E-6/hr REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.30 Ultimate source: plant operating experience (1 PWR plant-Ringhals 2)
Comment: Operating experience: total pop. 12. Operational time 39.91E+4 hours. 1 failure.
**ATABM**

**Component boundary:** sensor only  
**Operating mode:** operating  
**Operating environment:** normal  

**Generic failure mode:** degraded  
**Original failure mode:** reduced capability  

**FAILURE RATE OR PROBABILITY**  
Mean: $7.4 \times 10^{-7}$/hr  
95%: $1.2 \times 10^{-6}$/hr  
5%: $4.4 \times 10^{-7}$/hr  

Ultimate source: US plants LER reports evaluation  

Comment: Not applicable to BWR. Overall PWR data. Same value with and w/o command faults.

**ATAFM**

**Component boundary:** sensor only  
**Operating mode:** operating  
**Operating environment:** normal  

**Generic failure mode:** fail to function  
**Original failure mode:** inoperable  

**FAILURE RATE OR PROBABILITY**  
Mean: $1.7 \times 10^{-6}$/hr  
95%: $2.4 \times 10^{-6}$/hr  
5%: $1.2 \times 10^{-6}$/hr  

Ultimate source: US plants LER reports evaluation  

Comment: Not applicable to BWR. Overall PWR data. Same value with and w/o command faults.

**ATAFT**

**Component boundary:** detail n/a  
**Operating mode:** all  
**Operating environment:** normal  

**Generic failure mode:** fail to function  
**Original failure mode:** failure to function  

**FAILURE RATE OR PROBABILITY**  
Mean: $1.9 \times 10^{-3}$/d  
95%: $1.1 \times 10^{-2}$/d  
REPAIR TIME: 3 hours  

Source: Swedish Rel.data book, tbl.36  
Ultimate source: plant operating experience (5 BWR plants)  
ATV reports, LERs  
Comment: Operating experience: total pop.57. Number of demands 2160. No.of failures 4. a=0.061; b=32.9  
Critical failures reported on 1 plant.

**ATAKT**

**Component boundary:** detail n/a  
**Operating mode:** all  
**Operating environment:** normal  

**Generic failure mode:** spurious function  
**Original failure mode:** sourious function  

**FAILURE RATE OR PROBABILITY**  
Mean: $7.1 \times 10^{-7}$/hr  
95%: $1.8 \times 10^{-6}$/hr  
REPAIR TIME: 3 hours  

Source: Swedish Rel.data book, tbl.36  
Ultimate source: plant operating experience (7 BWR plants)  
Comment: Operating experience: total pop.728. Operational time 2250E+4 hours. No.of failures 16. a=0.0210; b=29500  
Critical failures reported on 6 plants.

**NCABM**

**Component boundary:** bistable only  
**Operating mode:** operating  
**Operating environment:** normal  

**Generic failure mode:** degraded  
**Original failure mode:** reduced capability  

**FAILURE RATE OR PROBABILITY**  
Mean: $1.2 \times 10^{-6}$/hr  
95%: $1.4 \times 10^{-6}$/hr  
5%: $1.1 \times 10^{-6}$/hr  

Ultimate source: US plants LER reports evaluation  

Comment: Comparators/bistables recive output from the conditioning systems in turn provide inputs to logic matrices. BWR core flux and flow only. Overall rate with command faults. W/o command $1.1 \times 10^{-6}$/hr.
NCAFH signal comparator bistable for core flux, level, flow, pressure, temperature
Component boundary: bistable only  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean: 5.2E-7/hr  95%: 6.8E-7/hr  5%: 4.0E-7/hr
Comment: Comparators/bistables receive input from the conditioning systems in turn provide input to logic matrices. BWR core flux and flow only. Overall rate with command faults. W/o command 4.3E-7/hr.

NCABE signal comparator bistable general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: degraded
FAILURE RATE OR PROBABILITY rec: 3.4E-7/hr  high: 1.1E-6/hr  low: 4.0E-8/hr
Comment: Reference IEEE 500 (1977) Failure mode "degraded" include: 1) functioned at improper signal level; 2) premature or delayed action

NCAFE signal comparator bistable general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY rec: 1.0E-6/hr  high: 3.5E-6/hr  low: 1.0E-7/hr
Comment: Reference IEEE 500 (1977) Failure mode "catastrophic" include: 1) functioned without signal; 2) no function with signal.

NCAFI signal comparator bistable general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 3.0E-7/d  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tab.5.1-1)  Ultimate source: expert opinion
Comment: IREP data base do not define failure mode for this component. Failure to operate is the most logical one and is in accordance with other sources. Reference: MIL-HDBK 217C

NSABM signal conditioning system for core flux, level, flow, pressure, temperature general
Component boundary: computational modules, summation amplifiers, power supply etc.  Operating mode: operating  Operating environment: normal
Generic failure mode: degraded  Original failure mode: reduced capacity
FAILURE RATE OR PROBABILITY mean: 1.8E-6/hr  95%: 2.0E-6/hr  5%: 1.6E-6/hr
Comment: Conditioning system is defined as conglomeration of components that receive output from sensing device and develop input for comparator. Overall rate, with command faults. W/o command 1.7E-6/hr.
NSAFM signal conditioning system for core flux, level, flow, pressure, temperature general
Component boundary: computational modules, summation amplifiers, power supply
Operating mode: operating
Operating environment: normal
Generic failure mode: fail to function
Original failure mode: inoperable
FAILURE RATE OR PROBABILITY
mean: 3.4E-6/hr
95%: 3.7E-6/hr
5%: 3.1E-6/hr
Source: NUREG 1740 (1984) (Table 18)
Ultimate source: US plants LER reports evaluation
Comment: Conditioning system is defined as conglomerate of components that receive output from sensing device and develop input for comparator. Overall rate, with command faults. W/o command 3.2E-6/hr

NMTAF signal modifier current-current transducer
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: all modes
Original failure mode: all modes
FAILURE RATE OR PROBABILITY
mean: 4.7E-6/hr
95%: 6.3E-6/hr
5%: 3.5E-6/hr
ERROR FACTOR: 1.3
REPAIR TIME: 3 hours
Source: HWR data
Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 6.6E+6 hours. 31 failures. "All modes" should be used instead: 1) no output, 2) high, 3) low output, 4) no change in output with change of input.

NMPAF signal modifier current-pneumatic transducer
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: all modes
Original failure mode: all modes
FAILURE RATE OR PROBABILITY
median: 7.3E-6/hr
95%: 3.1E-5/hr
5%: 5.7E-7/hr
ERROR FACTOR: 4.3
REPAIR TIME: 3 hours
Source: HWR data
Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 9.5E+4 hours. No failures. Repair time is estimated. "All modes" include: 1) no output, 2) high, 3) low output, 4) no change in output with change of input.

NMVAF signal modifier current-voltage transducer
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: all modes
Original failure mode: all modes
FAILURE RATE OR PROBABILITY
mean: 2.3E-5/hr
95%: 2.9E-5/hr
5%: 1.8E-5/hr
ERROR FACTOR: 1.2
REPAIR TIME: 3 hours
Source: HWR data
Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 2.3E+6 hours. 52 failures. "All modes" include: 1) no output, 2) high, 3) low output, 4) no change in output with change in input.

NMABE signal modifier general
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: degraded
Original failure mode: degraded
FAILURE RATE OR PROBABILITY
rec: 8.4E-7/hr
high: 1.6E-6/hr
low: 3.5E-7/hr
Source: IEEE 500 (1984) pg. 627
Ultimate source: expert opinion aggregation
Comment: Reference IEEE 500 (1977)
NMAF

signal modifier general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY  rec : 3.0E-7/hr high: 5.7E-7/hr low: 1.3E-7/hr
Comment: Reference IEEE 500 (1977) Failure mode "catastrophic" include 1) zero or maximum output;
2) no change in output with change in input.

NMSAF

signal modifier square root extractor
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 5.1E-6/hr 95%: 6.8E-6/hr 5%: 3.9E-6/hr  ERROR FACTOR: 1.3  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cum. operating time 6.2E+6 hours. 32 failures "All modes" include following: 1) no output, 2) high, 3) low output, 4) no change in output with change in input.

NMDAF

signal modifier voltage-pneumatic transducer
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 1.5E-6/hr 95%: 7.1E-6/hr 5%: 5.7E-7/hr  ERROR FACTOR: 2.8  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cum. operating time 67.5E+4 hours. 1 failure. "All modes" include following failure modes: 1) no output, 2) high, 3) low output, 4) no change in output with change in input.

UEHFB

solid state devices high power application
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 3.0E-6/hr max: 2.0E-5/hr min: 6.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment: NUREG 2815 do not define failure mode for this component. Failure to operate is the most logical one, and it is in accordance with other sources.

UEHFI

solid state devices high power application
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 3.0E-6/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (table 5.1-1)  Ultimate source: expert opinion
Comment: IREP data base do not define failure mode for this component. Failure to operate is the most logical one and is in accordance with other sources.
UEHFW  solid state devices high power application (current >=1 A or voltage >=28 V)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fails to function
FAILURE RATE OR PROBABILITY median: 3.0E-6/hr  95%: 3.0E-5/hr  5%: 3.0E-7/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear experience and from military data
Comment: The available data do not permit separation of the causes of failures in all cases, hence solid state devices failure modes are not independent. Large error factor due to difference in application.

UEHHW  solid state devices high power application (current >=1A or voltage >=28 V)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: fails shorted
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr  95%: 1.0E-5/hr  5%: 1.0E-7/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear experience and military data
Comment: The available data do not permit separation of causes of failure hence failure modes are not independent and should not be combined. Large error factor due to difference in application.

UELFB  solid state devices low power application general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 3.0E-6/hr  max: 2.0E-5/hr  min: 6.0E-8/hr
Source: NUREG 2815 (table C.I.)  Ultimate source: expert judgement and IREP data
Comment: NUREG 2815 do not define failure mode for this component. Failure to operate is the most logical one, and is in accordance with other sources.

UELFI  solid state devices low power application general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 3.0E-6/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: IREP data base do not define failure mode for this component. Failure to operate is the most logical one and is in accordance with other sources. Reference: MIL-HDBK 217C

UELFW  solid state devices low power application general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr  95%: 1.0E-5/hr  5%: 1.0E-7/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear and military experience and data
Comment: Failure modes are not independent. The relatively large error factor reflect variation from application to application.
UELHW  solid state devices low power application general
Component boundary: detail n/a   Operating mode: all   Operating environment: normal
Generic failure mode: short circuit   Original failure mode: fails short
FAILURE RATE OR PROBABILITY median: 1.0E-7/hr   95%: 1.0E-6/hr   5%: 1.0E-8/hr   ERROR FACTOR: 10
Source: WASH 1400  (table III 4-2)   Ultimate source: assessed from military experience and expert opinion
Comment: Failure modes are not independent. The relatively large error factor reflects variation from application to application.

ECMFT  static converter for reactor main coolant pumps
Component boundary: rectifier, inverter, continuous voltage equipment, transformer   Operating mode: operating   Operating environment: normal
Generic failure mode: fail to function   Original failure mode: loss of effective output
FAILURE RATE OR PROBABILITY mean: 4.1E-5/hr   95%: 1.4E-4/hr   REPAIR TIME: 28 hours
Source: Swedish Rel. data book, tbl.54   Ultimate source: plant operating experience (2 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 16. Operational time 19.7E+4 hours No. of failures 8. a=0.67; b=16500

YSDQA  strainer service water strainer (charging pump cooling system) duplex strainer
Component boundary: detail n/a   Operating mode: alternating   Operating environment: normal
Generic failure mode: plug   Original failure mode: plugged
FAILURE RATE OR PROBABILITY median: 2.0E-5/hr   ERROR FACTOR: 3
Source: NUREG 4550/Vol.3, tbl. IV.8-1   Ultimate source: Surry NPP operating experience
Comment: Normal environment in this case include raw water environment.

YSFQB  strainer/filter general
Component boundary: detail n/a   Operating mode: all   Operating environment: normal
Generic failure mode: plug   Original failure mode: plugged
FAILURE RATE OR PROBABILITY mean: 3.0E-5/hr   max: 2.0E-4/hr   min: 6.0E-7/hr
Source: NUREG 2815 (table C.1.)   Ultimate source: expert opinion and IREP data
Comment: For clear fluids. Contaminated fluids and fluids with heavy chemical burden should be considered on plant specific bases.

YSFQI  strainer/filter general
Component boundary: detail n/a   Operating mode: all   Operating environment: normal
Generic failure mode: plug   Original failure mode: plugged
FAILURE RATE OR PROBABILITY mean: 3.0E-5/hr   ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)   Ultimate source: expert opinion
Comment: Given value is for clear fluids only. Contaminated fluids or fluids with a heavy chemical burden should be considered on plant specific bases.
SDABM switch digital channel pressure/vacuum, pressure, level
Component boundary: digital channel Operating mode: operating Operating environment: normal
Generic failure mode: degraded Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean : 7.5E-6/hr 95%: 8.3E-6/hr 5%: 6.8E-6/hr
Comment: Overall rate with command faults. W/o command 7.1E-6/hr Pressure/vacuum and level applicable to BWR, and pressure applicable to PWR. BWR rate 5 times higher than PWR.

SDAFM switch digital channel pressure/vacuum, pressure, level
Component boundary: digital channel Operating mode: operating Operating environment: normal
Generic failure mode: fail to function Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean : 1.0E-6/hr 95%: 1.3E-6/hr 5%: 7.7E-7/hr
Comment: Overall rate with command faults. W/o command 8.9E-7/hr. Pressure/vacuum and level switches applicable to BWR, pressure applicable to PWR. BWR rate is order of magnitude higher than PWR.

SFABF switch flow
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: degraded Original failure mode: erratic operation
FAILURE RATE OR PROBABILITY mean : 3.4E-7/hr REPAIR TIME: 4 hours
Source: HWR data Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

SFAFF switch flow
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 1.7E-6/hr REPAIR TIME: 4 hours
Source: HWR data Ultimate source: HWR assessment
Comment: Ultimate source of data is not clear.

SFAKF switch flow
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY mean : 1.6E-6/hr REPAIR TIME: 4 hours
Source: HWR data Ultimate source: HWR assessment
Comment: Ultimate source of data is not known.
SFAE switch flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no function with signal
FAILURE RATE OR PROBABILITY rec: $9.8 \times 10^{-7}$/hr  high: $1.8 \times 10^{-6}$/hr  low: $8.0 \times 10^{-8}$/hr  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.578  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite and include some non-nuclear sources.

SFAFS switch flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no function with signal
FAILURE RATE OR PROBABILITY mean: $2.6 \times 10^{-7}$/hr
Source: Shoreham PRA, GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

SFAKE switch flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY rec: $8.6 \times 10^{-7}$/hr  high: $1.6 \times 10^{-6}$/hr  low: $8.0 \times 10^{-8}$/hr  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.578  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite and include some non-nuclear sources.

SFXFE switch flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no function with signal
FAILURE RATE OR PROBABILITY rec: $1.0 \times 10^{-8}$/cy  high: $4.0 \times 10^{-8}$/cy  low: $0.0 \times 0$/cy  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.578  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite.

SFXKE switch flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY rec: $1.0 \times 10^{-8}$/cy  high: $5.0 \times 10^{-8}$/cy  low: $0.0 \times 0$/cy  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.578  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite.
SLABF switch level
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: erratic operation
FAILURE RATE OR PROBABILITY mean : 7.2E-7/hr
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

SLAFF switch level
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 1.4E-6/hr  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

SLAKF switch level
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY mean : 3.2E-6/hr  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

SLAKE switch level general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY rec : 1.6E-6/hr  high: 3.0E-6/hr  low: 7.7E-7/hr  REPAIR TIME: 1.5 hours
Source: IEEE 500 (1984) pg.589  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite.

SLXFE switch level general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no change of output with change of input
FAILURE RATE OR PROBABILITY rec : 3.0E-8/cy  high: 6.0E-8/cy  low: 0.0E-0/cy  REPAIR TIME: 1.5 hours
Source: IEEE 500 (1984) pg.589  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure rate is composite.
SIAAF switch limit
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean: 3.3E-6/hr  95%: 4.0E-6/hr  5%: 2.9E-6/hr  ERROR FACTOR: 1.4  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 29.8E+6 hours. 100 failures. "All modes" include: 1) failure to operate, 2) spurious, 3) erratic operation. No data for other FM are given.

SIEKT switch limit electronic
Component boundary: limit switch only  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY  mean: 7.7E-7/hr  95%: 4.0E-6/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.38  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 249. Operational time 816E+4 hours. No. of failures 7.a=0.0481; b=62700. Critical failures at 3 plants. No critical failures for "failure to operate on demand".

SIAFB switch limit general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean: 6.0E-6/hr  max: 4.0E-6/hr  min: 8.0E-7/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment: Where limit switch is used as part of pump/valve, switch failure rate is included in pump/valve failure rate

SIAFI switch limit general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean: 1.0E-4/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Where limit switch is used as part of pump/valve, switch failure rate is included in pump/valve failure rate

SIAFW switch limit general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  median: 3.0E-4/d  95%: 1.0E-3/d  5%: 1.0E-4/d  ERROR FACTOR: 3
Source: WASH 1400 (table 111 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: The data do not uniquely separate the causes of failure, hence failure modes are not necessary independent. Failure to operate includes failures of contacts.
SMACF  switch manual
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY  mean: 4.6E-7/hr  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known. Number of demands in time is not known. Repair time conservatively estimated to be 3 hours.

SMAKF  switch manual
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY  mean: 3.4E-7/hr
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

SMACB  switch manual general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to transfer
FAILURE RATE OR PROBABILITY  mean: 1.0E-6/hr  max: 5.0E-6/hr  min: 2.0E-8/hr
Source: NUREG 2815 (table c.1.)  Ultimate source: expert judgement and IREP data
Comment:

SMACI  switch manual general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to transfer
FAILURE RATE OR PROBABILITY  mean: 3.0E-5/d  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:

SMACW  switch manual general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to transfer
FAILURE RATE OR PROBABILITY  median: 1.0E-5/d  95%: 3.0E-5/d  5%: 3.0E-6/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment:
SPAAF switch pressure
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 5.7E-6/hr 95%: 8.1E-6/hr 5%: 4.1E-6/hr ERROR FACTOR: 1.4 REPAIR TIME: 4 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Population not known. Cumulative component operating time 3.9E+6 hours. 22 failures. "All modes" incl: 1)spurious, 2) erratic oper., 3) failure to operate. Contrib. of 2) is negligible, 1) & 3) about equal.

SPAFB switch pressure
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 2.0E-7/hr max: 1.0E-6/hr min: 8.0E-8/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert judgement and IREP data
Comment:

SPAFF switch pressure
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 3.1E-6/hr 95%: 5.0E-6/hr 5%: 2.0E-6/hr ERROR FACTOR: 1.5
Source: HWR data Ultimate source: HWR operating experience
Comment: Operational data for this failure mode are not given, but probably included in "all modes".

SPAKF switch pressure
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: spurious function Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY mean: 2.2E-6/hr 95%: 4.0E-6/hr 5%: 1.4E-6/hr ERROR FACTOR: 1.6
Source: HWR data Ultimate source: HWR operating experience
Comment: Operational data for this failure mode are not given, probably included in "all modes".

SPAFE switch pressure general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: no function with signal
FAILURE RATE OR PROBABILITY rec: 4.0E-7/hr high: 1.9E-6/hr low: 1.0E-8/hr REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg. 556 Ultimate source: expert opinion aggregation and operating experience
Comment: Value is composite and include some non-nuclear sources For this component failure rate per hour and per cycle is given.
SPAFI switch pressure general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 1.0E-4/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion  
Comment: 

SPAFW switch pressure general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  median: 1.0E-4/d  95%: 3.0E-4/d  5%: 3.0E-5/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear, industrial and military experience and data  
Comment: Data do not uniquely separate causes of failures, hence failure modes are not necessary independent. Failure to operate includes failure of contacts.

SPAKE switch pressure general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY  rec : 7.0E-8/hr  high: 3.1E-7/hr  low: 0.0E-0/hr  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.556  Ultimate source: expert opinion aggregation and operating experience  
Comment: Value is composite and include some non-nuclear sources. For this component failure rate per hour and per cycle is given.

SPXFE switch pressure general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no function with signal
FAILURE RATE OR PROBABILITY  rec : 1.4E-7/cy  high: 3.0E-7/cy  low: 3.0E-8/cy  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.556  Ultimate source: expert opinion aggregation and operating experience  
Comment: Value is composite and include some non-nuclear sources. For this component failure rate per hour and per cycle is given.

SPXKE switch pressure general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY  rec : 1.4E-7/cy  high: 8.0E-7/cy  low: 1.0E-8/cy  REPAIR TIME: .6 hours
Source: IEEE 500 (1984) pg.556  Ultimate source: expert opinion aggregation and operating experience  
Comment: Value is composite and include some non-nuclear sources. For this component failure rate per hour and per cycle is given.
STABF switch temperature
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: erratic operation
FAILURE RATE OR PROBABILITY  mean : 1.8E-7/hr
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

STAFF switch temperature
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 5.3E-7/hr
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

STAKF switch temperature
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: spurious operation
FAILURE RATE OR PROBABILITY  mean : 5.5E-7/hr
Source: HWR data  Ultimate source: HWR assessment
Comment: Ultimate data source is not known.

STAOS switch temperature
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fails to open
FAILURE RATE OR PROBABILITY  mean : 3.3E-7/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

STAFE switch temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no function with signal
FAILURE RATE OR PROBABILITY  rec : 1.2E-7/cy  high: 2.4E-7/cy  low: 2.0E-8/cy  REPAIR TIME: .5 hours
Source: IEEE 500 (1984) pg.534  Ultimate source: expert opinion aggregation and operating experience
Comment: Composite value for this component failure rate per hour and per cycle is given.
STAFE switch temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no function with signal
FAILURE RATE OR PROBABILITY  rec : 2.0E-7/hr  high: 3.9E-7/hr  low: 5.0E-8/hr  REPAIR TIME: .5 hours
Source: IEEE 500 (1984) pg.534  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite. For this component failure rate per hour and per cycle is given.

STAFS switch temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY  mean : 2.3E-6/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

STAKE switch temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY  rec : 2.3E-7/cy  high: 4.5E-7/cy  low: 6.0E-8/cy  REPAIR TIME: .5 hours
Source: IEEE 500 (1984) pg.534  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of different types and data sources for temperatre switches. For this component failure rate per hour and per cycle is given.

STXKE switch temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: spurious function  Original failure mode: functioned without signal
FAILURE RATE OR PROBABILITY  rec : 1.4E-7/cy  high: 2.9E-7/cy  low: 2.0E-8/cy  REPAIR TIME: .5 hours
Source: IEEE 500 (1984) pg.534  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite. For this component failure rate per hour and per cycle is given.

SQAFB switch torque general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 2.0E-7/hr  max: 1.0E-6/hr  min: 6.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment: Where torque switch is used as a part of pump/valve, switch failure rate is included in pump/valve rate
SQAFI switch torque general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean: 1.0E-4/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Where torque switch is used as part of pump/valve, switch failure rate is included in pump/valve failure rate.

SQAFW switch torque general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  median: 1.0E-4/d  95%: 3.0E-4/d  5%: 3.0E-5/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear and military experience and data sources
Comment: Data do not uniquely separate the causes of failure, hence failure modes are not necessary independent. Failure to operate include failures of contacts.

SCAHU switch contacts general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short across NO/NC switches
FAILURE RATE OR PROBABILITY  median: 1.0E-8/hr  95%: 1.0E-7/hr  5%: 1.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: assessed from nuclear and military experience and data
Comment: Data do not uniquely separate causes of failures, hence failure modes are not necessary independent.

SCCDW switch contacts general
Component boundary: detail n/a  Operating mode: normally closed  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: failure of NC contacts by opening, given no sw.opérât.
FAILURE RATE OR PROBABILITY  median: 3.0E-8/hr  95%: 3.0E-7/hr  5%: 3.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: ultimate data source is not known
Comment: The data do not uniquely separate the causes of failure, hence failure modes are not necessary independent.

SCOCW switch contacts general
Component boundary: detail n/a  Operating mode: normally open  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure of NO contacts to close, given switch operation
FAILURE RATE OR PROBABILITY  median: 1.0E-7/hr  95%: 1.0E-6/hr  5%: 1.0E-8/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: ultimate data source is not known
Comment: Data do not uniquely separate causes of failure, hence failure modes are not necessary independent.
SCACS switch contacts (relay HFA)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: coil fails to operate
FAILURE RATE OR PROBABILITY mean : 4.0E-7/hr
Source: Shoreham PRA,GE data(tB.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment: It was not possible to identify this component and failure mode in other sources.

SCAOS switch contacts (relay HFA)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: coil fails to open
FAILURE RATE OR PROBABILITY mean : 8.0E-8/hr
Source: Shoreham PRA,GE data(tB.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment: It was not possible to identify this component and failure mode in other sources.

JTFTH tank storage FWST
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: rupture during operation
FAILURE RATE OR PROBABILITY mean : 2.6E-8/hr 95%: 7.4E-8/hr 5%: 7.6E-10/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-8/hr. Operating experience 1.36E+5 hours of operation, no failures.

JTRTH tank storage RWST
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: rupture during operation
FAILURE RATE OR PROBABILITY mean : 2.7E-8/hr 95%: 7.6E-8/hr 5%: 7.6E-10/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-8/hr. Operating experience 1.36E+5 hours of operation, no failures.

EBAB terminal board general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: short circuit Original failure mode: short to adjacent circuit
FAILURE RATE OR PROBABILITY mean : 3.0E-7/hr max: 2.0E-6/hr min: 6.0E-9/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert judgement and IREP data
Comment: Given value is per terminal
EBAH1 terminal board general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short to adjacent circuit
FAILURE RATE OR PROBABILITY  mean: 3.0E-7/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Given value is per terminal

EBAHW terminal board general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short to adjacent circuit
FAILURE RATE OR PROBABILITY  median: 1.0E-8/hr  95%: 1.0E-7/hr  5%: 1.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: ultimate source not known
Comment: Data do not permit unique separation of failure modes between wires and terminal boards, so should not be combined. Data for terminal boards are given for cases where unique effects exist.

EBAIB terminal board general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open circuit
FAILURE RATE OR PROBABILITY  mean: 3.0E-7/hr  max: 2.0E-6/hr  min: 6.0E-9/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment: Given value is per terminal

EBAII terminal board general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open circuit
FAILURE RATE OR PROBABILITY  mean: 3.0E-7/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Given value is per terminal

EBAIW terminal board general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open connection
FAILURE RATE OR PROBABILITY  median: 1.0E-7/hr  95%: 1.0E-6/hr  5%: 1.0E-8/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-2)  Ultimate source: ultimate data source not known
Comment: Data do not permit unique separation of failure modes between wires and terminal boards, so should not be combined. Data for terminal boards are given for cases where unique effects exist.
TA2FH transformer 220/120 V
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 2.5E-6/hr 95%: 5.2E-6/hr 5%: 5.1E-7/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.6E-6/hr. Operating experience 5.4E+5 hours of operation, 2 failures.

TA5FH transformer 50/6 kV
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 1.3E-6/hr 95%: 2.5E-6/hr 5%: 2.8E-7/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.6E-6/hr. Operating experience 1.4E+5 hours of operation, no failures.

TA6FH transformer 6kV/380 V
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 4.9E-7/hr 95%: 1.1E-6/hr 5%: 8.6E-8/hr
Source: Old PWR Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 6.9E-7/hr. Operating experience 8.2E+5 hours of operation, no failures.

TA8FH transformer 8 kV / 6 kV
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean : 1.3E-6/hr 95%: 2.5E-6/hr 5%: 2.8E-7/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.6E-6/hr. Operating experience 1.4E+5 hours of operation, no failures.

TADFO transformer dry 4 kV/600 V
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: operational failure
FAILURE RATE OR PROBABILITY mean : 4.8E-7/hr 95%: 1.2E-6/hr 5%: 2.1E-8/hr REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior:IEEE 500(1977)(pg.300), rec=median;max=80% of distribution Operating experience: 4.34E+5 hours of operation, no failures.
Repair time is mean generic maintenance duration.
TAEFO transformer dry 600 V/208 V
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 3.1E-7/hr  95%: 7.8E-7/hr  5%: 5.7E-9/hr  REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tabl.b-1.)  Ultimate source: generic data updated with plant specific operational experience
Comment: Prior:IEEE 500 (1977) pg.299. rec=median; max=80% of distribution. Operating experience: 8.2E+5 hours of operation, no failures. Repair time is mean generic maintenance duration.

TTSFE transformer auto transformer liquid filled, single phase all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec : 4.5E-7/hr  high: 2.0E-6/hr  low: 1.3E-7/hr
Source: IEEE 500 (1984) pg.397  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of 7 different voltage levels See failure mode comment IEEE main transformer composite

TTTFE transformer auto transformer liquid filled, three phase all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec : 1.5E-6/hr  high: 2.7E-6/hr  low: 4.0E-7/hr
Source: IEEE 500 (1984) pg.405  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of 7 different voltage levels Failure mode "no output" include 1) automatic removal by protective circuitry; 2) manual removal; 3) open circuit. Dominant contrib. #1

TAAAB transformer general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 6.0E-7/hr  max: 4.0E-6/hr  min: 3.0E-7/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:

TAAAI transformer general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 1.0E-6/hr  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:
TAAFG transformer general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY median: 1.5E-6/hr ERROR FACTOR: 5
Source: German Risk Study (tb.F3,7-1) Ultimate source: generic data
Comment: In the table F3,7-1 failure mode is missing. Failure mode "failure to operate" was assumed on the bases of generic sources included. "Failure to operate" include "open" and "short" circuit.

TAAHW transformer general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: short circuit Original failure mode: short primary to secondary
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr 95%: 3.0E-6/hr 5%: 3.0E-7/hr ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear, industrial and military experience and data

TAAIW transformer general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: open circuit Original failure mode: open circuit, primary to secondary
FAILURE RATE OR PROBABILITY median: 1.0E-6/hr 95%: 3.0E-6/hr 5%: 3.0E-7/hr ERROR FACTOR: 3
Source: WASH 1400 (table III 4-2) Ultimate source: assessed from nuclear, industrial and military experience and data

TABFZ transformer general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: fail during operation
FAILURE RATE OR PROBABILITY mean: 1.7E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
Comment: Prior: IEEE 500(1977)(pg.300) transformer 601V-15kV, prior failure mode=all modes
Operating experience: 3.0E+5 hours of operation, 1 failure.

TA6FT transformer general Voltage <= 6 kv
Component boundary: transformer, relay protection, coolers, supervision, monitors Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: interruption
FAILURE RATE OR PROBABILITY mean: 7.9E-7/hr 95%: 3.5E-6/hr REPAIR TIME: 10 hours
Source: Swedish Rel.data book, tbl.47 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 129.0 operational time 379E+4 hours No. of failures 3. Critical failures occurred at two plants only. a=0.0345; b=43600
TM2FO  transformer high voltage outdoor
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 1.4E-6/hr  95%: 3.5E-6/hr  5%: 1.5E-7/hr  REPAIR TIME: 10.8 hours
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data upgraded with plant operating experience
Comment: Prior:IEEE 500 (1977)(pg.315), rec=median; max=80%. FM"catastrophic" seems to include load side protection). Op.exp. 81,900 hours of operation, no failures. Repair time is generic maintn. duration.

TICFE  transformer instrument transformer current transformer all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec : 2.6E-7/hr  high: 4.9E-7/hr  low: 1.1E-7/hr
Source: IEEE 500 (1984) pg.417  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of two different voltage levels. Failure mode "no output" include no output due to: 1) open circuit 2) shorts.

TIPFE  transformer instrument transformer potential transformer all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec : 4.2E-7/hr  high: 1.0E-6/hr  low: 2.7E-7/hr
Source: IEEE 500 (1984) pg.414  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of two different voltage levels. Failure mode "no output" include no output due to: 1) open circuit 2) shorts.

TSAFE  transformer main power generator or unit transformer liquid filled, single phase all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec : 2.8E-7/hr  high: 1.8E-6/hr  low: 3.0E-8/hr
Source: IEEE 500 (1984) pg.348  Ultimate source: expert opinion aggregation and operating experience
Comment: This is a composite value of all voltage levels of main, liquid filled single phase transformers. Failure mode include: 1) autom. removal; 2) manual removal; 3) open circuit. #1 is dominant.

TS2FE  transformer main power generator or unit transformer liquid filled, single phase voltage 2-30 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY  rec : 2.2E-7/hr  high: 3.9E-7/hr  low: 9.5E-8/hr
Source: IEEE 500 (1984) pg.347  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode includes no output due to: 1) automatic removal by protective circuitry; 2) manual removal; 3) open circuit.
**TS4FE** transformer main power generator or unit transformer liquid filled, single phase voltage 146-242 kV
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 3.2E-7/hr high: 6.2E-7/hr low: 2.5E-7/hr
Source: IEEE 500 (1984) pg.350 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode "no output" include: 1) automatic removal by protect. circuitry; 2) manual removal; 3) open circuit. #1 is order of magnitude higher than #2) and #3).

**TS5FE.** transformer main power generator or unit transformer liquid filled, single phase voltage 347-550 kV
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 1.2E-6/hr high: 1.9E-6/hr low: 5.3E-7/hr
Source: IEEE 500 (1984) pg.352 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode "no output" include: 1) automatic removal by protect. circuitry; 2) manual removal; 3) open circuit. #1 is order of magnitude higher than #2) and #3).

**TMAFE** transformer main power generator or unit transformer liquid filled, three phase all voltage levels
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 5.8E-7/hr high: 1.6E-6/hr low: 1.0E-7/hr
Source: IEEE 500 (1984) pg.354 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of all voltage levels. Failure mode include: 1) automatic; 2) manual removal; 3) open circuit. #1 is order of magnitude higher than #2) and #3).

**TM4FE** transformer main power generator or unit transformer liquid filled, three phase voltage 146-242 kV
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 1.1E-6/hr high: 1.5E-6/hr low: 5.0E-7/hr
Source: IEEE 500 (1984) pg.358 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode "no output" include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1) (more than order-of-magnitude)

**TM2FE** transformer main power generator or unit transformer liquid filled, three phase voltage 2-30 kV
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 3.4E-7/hr high: 5.1E-7/hr low: 1.8E-7/hr
Source: IEEE 500 (1984) pg.355 Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode "no output" include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1).
TMSFE  transformer main power generator or unit transformer liquid filled, three phase voltage 347-550 kV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output(catastrophic)
FAILURE RATE OR PROBABILITY  rec : 7.4E-7/hr  high: 1.4E-6/hr  low: 4.3E-7/hr
Source: IEEE 500 (1984) pg.360  Ultimate source: expert opinion aggregation and operating experience
Comment: Failure mode "no output" include: 1) automatic removal; 2) manual removal; 3) open circuit. #1 is order of magnitude higher than #2 and #3.

TMSFT  transformer main transformer Voltage= 400kV,130kV
Component boundary: transformer,coolers,relay protection, supervision, monitors  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: interruption
FAILURE RATE OR PROBABILITY  mean : 3.5E-6/hr  95%: 1.8E-5/hr  REPAIR TIME: 38 hours
Source: Swedish Rel.data book, tbl.45  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERS
Comment: Operating experience: total pop. 10. Operating time 28.8E+4 hours. No.of failures 1. Most frequent failures are cooling fan failures which are not critical failures of the transform. a=0.195;b=56200

TVRFO  transformer regulating 120 V AC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: operational failure
FAILURE RATE OR PROBABILITY  mean : 2.0E-6/hr  95%: 4.2E-6/hr  5%: 4.4E-9/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: IEEE 500 (1977)(pg.298) Failure mode "catastrophic failure" Operating experience: 48.213 hours of operation, no failures rec=median; max=80% of distribution

TETFE  transformer station service including excitation dry type, three phase all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output(catastrophic)
FAILURE RATE OR PROBABILITY  rec : 4.0E-7/hr  high: 1.4E-6/hr  low: 1.1E-7/hr
Comment: Given value is composite of three different voltage levels Failure mode include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1.

TESFE  transformer station service including excitation dry type, single phase all voltage levels
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output(catastrophic)
FAILURE RATE OR PROBABILITY  rec : 2.7E-7/hr  high: 2.3E-6/hr  low: 8.0E-8/hr
Source: IEEE 500 (1984) pg.326  Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of three different voltage levels. Failure mode include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1.
TEGFE transformer station service including excitation liquid filled, single phase all voltage level (0-40 kV)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 2.2E-7/hr high: 1.1E-6/hr low: 8.6E-8/hr
Source: IEEE 500 (1984) pg.318 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of three different voltage levels. Failure mode include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1).

TENFE transformer station service including excitation liquid filled, three phase all voltage levels (0-40 kV)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 1.1E-7/hr high: 8.1E-7/hr low: 5.4E-8/hr
Source: IEEE 500 (1984) pg.322 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of three different voltage levels. Failure mode include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1).

TXAFT transformer station start and auxiliary transformer Voltage levels: 130/6 kV, 70/6 kV, 20/6 kV
Component boundary: transformer, coolers, relay protection, supervisions, monitors Operating mode: operating Operating environment: normal
Generic failure mode: fail to function Original failure mode: interruption
FAILURE RATE OR PROBABILITY mean : 2.0E-6/hr 95%: 1.1E-5/hr REPAIR TIME: 5 hours
Source: Swedish Rel.data book, tbl.46 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 17. Operational time 51.2E+4 hours No. of failures 1.
\[ a=0.101; b=51800 \]

TUSFE transformer substation liquid filled, single phase all voltage levels
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 5.1E-7/hr high: 2.6E-6/hr low: 9.0E-8/hr
Source: IEEE 500 (1984) pg.380 Ultimate source: expert opinion aggregation and operating experience
Comment: see failure mode comment IEEE 500 main transformer composite Failure mode "no output" include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1).

TUTFE transformer substation liquid filled, three phase all voltage levels
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to function Original failure mode: no output (catastrophic)
FAILURE RATE OR PROBABILITY rec : 8.0E-7/hr high: 1.9E-6/hr low: 3.1E-7/hr
Source: IEEE 500 (1984) pg.388 Ultimate source: expert opinion aggregation and operating experience
Comment: Given value is composite of all voltage level failure mode "no output" include: 1) automatic removal; 2) manual removal; 3) open circuit. Dominant contributor is #1).
LFF8E  transmitter flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: degraded
FAILURE RATE OR PROBABILITY  rec : 1.5E-6/hr  high: 2.8E-6/hr  low: 6.3E-7/hr
Comment: Reference IEEE 500 (1977) Failure mode "degraded" include: 1) erratic; 2) high; 3) low output

LFFFE  transmitter flow general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY  rec : 1.5E-6/hr  high: 2.8E-6/hr  low: 6.2E-7/hr
Comment: Reference IEEE 500 (1977) Failure mode "catastrophic" include: 1) zero or maximum output; 2) no change in output with change in input. Dominant #1.

LFF8T  transmitter flow general
Component boundary: transmitter only  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: signal failure
FAILURE RATE OR PROBABILITY  mean : 3.4E-6/hr  95%: 1.9E-5/hr  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.33  Ultimate source: plant operating experience (5 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 97. Operational time 358E+4 hours. No. of failures 12. a=0.101; b=30200
Critical failures reported on 5 plants.

LAD8F  transmitter flow, level, pressure (DP cells)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: erratic output
FAILURE RATE OR PROBABILITY  mean : 7.3E-7/hr  95%: 1.1E-6/hr  5%: 2.3E-7/hr  ERROR FACTOR: 1.4  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR assessment
Comment: Operational data for this FM are not given, but probably included in "all modes". Degraded failure rate should include this, high and low output. Combined failure rate mean=2.0E-6/hr, 95%=3.0E-6/hr.

LAD8F  transmitter flow, level, pressure (DP cells)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: no output
FAILURE RATE OR PROBABILITY  mean : 1.2E-6/hr  95%: 1.6E-6/hr  5%: 9.0E-7/hr  ERROR FACTOR: 1.3  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Operational data for this failure mode are not given, but probably included in "all modes". Catastrophic failures are this and "no change in output with change in input" summed together mean=1.9E-6/hr.
LADAF  transmitter flow, level, pressure (DP cells)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 4.1E-6/hr  95%: 4.8E-6/hr  5%: 3.5E-6/hr  ERROR FACTOR: 1.2
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cum. component operating time 28.5E+6 hours. 116 failures. "All modes" incl: 1) no output, 2) high, 3) low output, 4) no change in output with change in m., 5) erratic. All equally contribute.

LADBM  transmitter flow, level, pressure general
Component boundary: transmitter only  Operating mode: operating  Operating environment: normal
Generic failure mode: degraded  Original failure mode: reduced capability
FAILURE RATE OR PROBABILITY mean : 3.3E-6/hr  95%: 3.6E-6/hr  5%: 3.0E-6/hr
Comment: Overall rate, w/ command faults. W/ o command faults 3.2E-6/hr. Only the flow transmitters from BWRs are included. PWR rate is two orders of magnitude higher than BWR.

LADFM  transmitter flow, level, pressure general
Component boundary: transmitter only  Operating mode: operating  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: inoperable
FAILURE RATE OR PROBABILITY mean : 1.9E-6/hr  95%: 2.3E-6/hr  5%: 1.6E-6/hr
Comment: Overall rate, w/ command faults. W/ o command faults 1.7E-6/hr. Only the flow transmitter for BWR. PWR rate is almost two orders of magnitude higher than BWR.

LLLBE  transmitter level general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: degraded
FAILURE RATE OR PROBABILITY rec : 1.1E-6/hr  high: 2.4E-6/hr  low: 6.0E-6/hr
Comment: Reference IEEE 500 (1977) Failure mode "degraded" include: 1) erratic; 2) high; 3) low output all contribute about equal to given rate.

LLLFE  transmitter level general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY rec : 1.4E-6/hr  high: 3.0E-6/hr  low: 7.1E-7/hr
Comment: Reference IEEE 500 (1977) Failure mode "catastrophic" include: 1) zero or max output; 2) no change in output w/ change in input. Both about equal.
**LLLFT**  
**transmitter level general**  
Component boundary: level transmitter only  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: signal failure  

**FAILURE RATE OR PROBABILITY**  
mean: $3.8 \times 10^{-6}$/hr  
95%: $2.0 \times 10^{-5}$/hr  
REPAIR TIME: 2 hours  

Source: Swedish Rel.data book, tbl.35  
Ultimate source: plant operating experience (5 BWR plants), ATV reports, LERs  
Comment: Operating experience: total pop. 72. Operational time $289 \times 10^4$ hours  
No. of failures 11.  
\[ a = 0.188; \ b = 49500 \]

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**LPPBE**  
**transmitter pressure general**  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: degraded  
Original failure mode: degraded  

**FAILURE RATE OR PROBABILITY**  
rec: $6.4 \times 10^{-7}$/hr  
high: $1.2 \times 10^{-6}$/hr  
low: $1.5 \times 10^{-7}$/hr  

Source: IEEE 500 (1984) pg.552  
Ultimate source: expert opinion aggregation  
Comment: Reference IEEE 500 (1977) Failure mode include: 1) erratic; 2) high; 3) low output.  
About equal contribution.

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**LPPFE**  
**transmitter pressure general**  
Component boundary: detail n/a  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: catastrophic  

**FAILURE RATE OR PROBABILITY**  
rec: $8.8 \times 10^{-7}$/hr  
high: $1.7 \times 10^{-6}$/hr  
low: $2.0 \times 10^{-7}$/hr  

Source: IEEE 500 (1984) pg.552  
Ultimate source: expert opinion aggregation  
Comment: Reference IEEE 500 (1977) Failure mode "catastrophic" include: 1) zero or max. output; 2) no change in output with change in input. About equal contribution.

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**LPPFT**  
**transmitter pressure general**  
Component boundary: pressure transmitter only  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: signal failure  

**FAILURE RATE OR PROBABILITY**  
mean: $1.8 \times 10^{-6}$/hr  
95%: $1.0 \times 10^{-5}$/hr  
REPAIR TIME: 2 hours  

Source: Swedish Rel.data book, tbl.29  
Ultimate source: plant operating experience (5 BWR plants), ATV reports, LERs  
Comment: Operating experience: total pop. 203. Operational time $820 \times 10^4$ hours  
No. of failures 15.  
\[ a = 0.0558; \ b = 30500 \]

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**LPPFY**  
**transmitter pressure general**  
Component boundary: pressure transmitter only  
Operating mode: all  
Operating environment: normal  
Generic failure mode: fail to function  
Original failure mode: signal failure  

**FAILURE RATE OR PROBABILITY**  
mean: $2.5 \times 10^{-6}$/hr  
REPAIR TIME: 5 hours  

Source: Swedish Rel.data book, tbl.29  
Ultimate source: plant operating experience (1 PWR plant: Ringhals 2), ATV reports  
Comment: Operating experience: total pop. 12. Operational time $39.91 \times 10^4$ hours  
1 failure
LXRFY transmitter pressure difference general
Component boundary: pressure difference transmitter only  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: signal failure
FAILURE RATE OR PROBABILITY  mean : 8.4E-7/hr  REPAIR TIME: 2 hours
Source: Swedish Rel.data book, tbl.31  Ultimate source: plant operating experience (1 PWR plant: Ringhals 2), ATV reports
Comment: Operating experience: total pop. 72. Operational time 239.5E+4 hours No.of failure 2.

LXRTF transmitter pressure difference general
Component boundary: pressure difference transmitter only  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: signal failure
FAILURE RATE OR PROBABILITY  mean : 1.4E-6/hr  95%: 8.3E-6/hr  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.31  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop 132. Operational time 558E+4 hours No.of failures 8. a=0.0942; b=66200
Critical failures reported on 4 plants

LTTAF transmitter temperature
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 4.9E-6/hr  95%: 9.2E-6/hr  5%: 2.7E-6/hr  ERROR FACTOR: 1.7  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Population not known. Cum. component operating time 1.4E+6 hours. 7 failures.

LTTBE transmitter temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: degraded  Original failure mode: degraded
FAILURE RATE OR PROBABILITY  rec : 3.7E-7/hr  high: 3.2E-6/hr  low: 1.8E-7/hr
Source: IEEE 500 (1984) pg.531  Ultimate source: expert opinion aggregation
Comment: Reference IEEE 500(1977) Failure mode "degraded" include: 1)erratic; 2)high; 3)low output.
#1) and #2) order of magnitude higher than #3).

LTTEE transmitter temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: catastrophic
FAILURE RATE OR PROBABILITY  rec : 3.7E-7/hr  high: 3.3E-6/hr  low: 1.9E-7/hr
Source: IEEE 500 (1984) pg.531  Ultimate source: expert opinion aggregation
Comment: Reference IEEE 500 (1977) Failure mode include: 1)zero or max. output 2)no change of output with change of input. Dominant contributor is #1).
LTFT transmitter temperature general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: signal failure
FAILURE RATE OR PROBABILITY mean : 2.8E-6/hr  95%: 1.5E-5/hr  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.37  Ultimate source: plant operating experience (6 BWR plants), ATV reports, LERs
Comment: Operating experience: total pop. 132. Operational time 289E+4 hours. No. of failures 8. a=0.0579; b=20900
Critical failures reported on 5 plants.

JUCAE turbine combustion general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 5.7E-4/hr  high: 2.0E-3/hr  low: 2.0E-5/hr
Comment: Given value is composite of different sources, NUREG 2232, EPRI report No.AP 2321 Mar.82, EPRI Journal Mar.82 pp 37.
Include gas and oil combustion

JUSAE turbine steam driven condensing, single stage, 500-999 HP
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 4.0E-4/hr  high: 1.6E-3/hr  low: 1.0E-4/hr
Comment: reference: NUREG 2232

JUPAE turbine steam driven general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 2.1E-4/hr  REPAIR TIME: 81 hours
Comment: Given value is composite of several different sources, EPRI report No.46, Aug.76, EPRI report No.2205, Feb.82, EPRI Journal, Mar.82, pp37
Value is composite of different application as well.

JUNAE turbine steam driven non condensing 1000-5000 HP
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.0E-4/hr  high: 1.0E-2/hr  low: 1.0E-6/hr
Comment: reference: NUREG 2232 (?)
JUMAE  turbine steam driven non condensing, multi stage, less than 500 HP
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 2.0E-4/hr  high: 2.0E-3/hr  low: 2.0E-5/hr
Comment: reference :NUREG 2232

JUNFS  turbine turbine/HPCI assembly
Component boundary: detail n/a  Operating mode: n/a  Operating environment: normal
Generic failure mode: fail to function  Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY  mean : 1.0E-5/hr
Source: Shoreham PRA,GE data(tb.A.2.1)  Ultimate source: evaluation of BWR operating experience
Comment:

VAOCS  valve ADS depressurization valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY  mean : 7.0E-6/hr
Source: Shoreham,PRA GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

VWAAE  valve angle valve
Component boundary: detail n/a (generally excludes driver)  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 3.3E-6/hr  high: 2.3E-3/hr  low: 2.5E-7/hr
Comment: Reference:NUREG 2232. Given value is composite of different sizes and operators of angle valves.FM"all modes"is sum of catastrophic (failed to operate,plugged,ext.leakage),degraded and incipient.

VWBAE  valve ball valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 2.4E-6/hr  high: 8.8E-4/hr  low: 4.4E-7/hr  REPAIR TIME: 1.3 hours
Comment: References:NUREG 2232,Corps of engineers,6/M data base,NPRD-2. Given value is composite of different sources,sizes and operators of ball valves.Per cycle value 6.0E-5/cy.FM see comment angle vlv
VWTAE valve butterfly valve

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes

FAILURE RATE OR PROBABILITY  mean: 1.2E-6/hr  95%: 3.5E-4/hr  5%: 3.0E-8/hr  REPAIR TIME: 1.9 hours

Comment: references: see ball valve. FM see comment angle valve. Given value is composite of different sources and different sizes and operators of butterfly valves.

VWDAF valve condenser steam discharge valve

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes

FAILURE RATE OR PROBABILITY  mean: 2.3E-5/hr  95%: 3.1E-5/hr  5%: 1.7E-5/hr  ERROR FACTOR: 1.3  REPAIR TIME: 12 hours

Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.24. Operating time 126E+4 hours. 29 failures. "all modes" incl: 1) external, 2) internal leak, 3) fail to close, 4) fail to open, 5) limit switch, 6) faulty indication, 7) out of calibration, 8) unspecified

VWDEF valve condenser steam discharge valve

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close

FAILURE RATE OR PROBABILITY  mean: 3.2E-6/hr  95%: 7.3E-6/hr  5%: 1.6E-6/hr  ERROR FACTOR: 2.0  REPAIR TIME: 5 hours

Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.24. Cumulative operating time 126E+4 hours. 4 failures. Number of demands per operating time is not known.

VWDOF valve condenser steam discharge valve

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open

FAILURE RATE OR PROBABILITY  mean: 6.3E-6/hr  95%: 1.1E-5/hr  5%: 3.7E-6/hr  ERROR FACTOR: 1.7  REPAIR TIME: 5 hours

Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.24. Cumulative operating time 126E+4 hours. 8 failures. Number of demands per operating time is not known.

VWDYF valve condenser steam discharge valve

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak

FAILURE RATE OR PROBABILITY  mean: 4.8E-6/hr  95%: 9.4E-6/hr  5%: 2.6E-6/hr  ERROR FACTOR: 1.8  REPAIR TIME: 42 hours

Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.24. Cumulative component operating time 126E+4 hours. No. of failures 6.
VWPAE valve diaphragm
Component boundary: detail n/a (generally exclude driver) Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 2.8E-6/hr high: 6.2E-5/hr low: 1.2E-6/hr REPAIR TIME: .9 hours
Comment: ref: Corps of Engineers R/M data base, NPRD-2, NUREG 0666 Given value is composite of different sources, operators, sizes and applications of diaphragm valves. FM see comment angle valve.

VWFAE valve flow control 1/2 inch, air fixed flow
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 5.5E-6/hr high: 1.0E-5/hr low: 2.0E-6/hr REPAIR TIME: 1 hour
Comment: reference: R/M data base FM see comment angle valve.

VWGAE valve gate
Component boundary: detail n/a (generally exclude driver) Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.9E-6/hr high: 4.6E-5/hr low: 1.7E-7/hr REPAIR TIME: 3.3 hours
Source: IEEE 500 (1984) pg.1109 Ultimate source: expert judgement and experience
Comment: ref: Corps of Engineers R/M data base, NPRD-2, NUREG 2232 Given value is composite of different sources, operators, sizes and applications of gate valves. FM see comment angle valve.

VWLAE valve globe valve
Component boundary: detail n/a (generally exclude driver) Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 3.5E-6/hr high: 1.7E-4/hr low: 1.8E-7/hr REPAIR TIME: 1.7 hours
Comment: references: same as gate valve Given value is composite of different sources, application, sizes and operators of globe valves. FM see comment angle valve.

VWEGG valve high pressure shifting valve (steam dump)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: not functioning
FAILURE RATE OR PROBABILITY median: 4.0E-2/d ERROR FACTOR: 10
Source: German Risk Study (tb.F3,7-1) Ultimate source: operating experience
Comment: This type of valve should switch over 30 seconds. In 126 trials it did not switch properly in 12 cases. That gives even higher rate but given value is assessed to be adequate for emergency cases.
VWNAE valve needle valve
Component boundary: detail n/a (generally exclude driver) Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 1.2E-6/hr high: 4.2E-6/hr low: 9.0E-8/hr 
REPAIR TIME: .8 hours
Comment: ref:see globe valve Given value is composite of different sources, applications, sizes and operators of needle valves. FM see comment angle valve.

VWJAE valve nozzle valve
Component boundary: detail n/a (generally exclude operator) Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 5.4E-6/hr high: 6.5E-4/hr low: 3.2E-7/hr 
Comment: reference:NUREG 2232 Given value is composite of different sizes and operators of nozzle valves. FM see comment angle valve.

VUKET valve pilot valve pressure relief system pilot valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to reclose
FAILURE RATE OR PROBABILITY mean : 1.2E-3/d 95%: 6.8E-3/d
Source: Swedish Rel.data book, tbl.22 Ultimate source: operating experience (7 BWR plants), ATV reports, LERs, plant inform.
Comment: Population 55. Number of demands 845. 1 failure. Critical failure at one plant.
   a=0.0684;b=57.7

VUKOT valve pilot valve pressure relief system pilot valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean : 8.3E-3/d 95%: 4.7E-2/d
Source: Swedish Rel.data book, tbl.22 Ultimate source: operating experience (7 BWR plants)
Comment: Total population 55. 845 demands per operational time. 7 failures Critical failures reported on 4 plants.
   a=0.13;b=15.6

VWJAE valve plug valve
Component boundary: detail n/a (generally excludes operator) Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 2.6E-6/hr high: 3.2E-3/hr low: 1.4E-7/hr 
REPAIR TIME: 1.2 hours
Comment: reference:see needle valve. Given value is composite of different sources, applications, sizes, and operators of plug valves. FM see comment angle valve
VWXAF  valve pressure regulating
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.3E-6/hr  95%: 1.6E-6/hr  5%: 1.1E-6/hr  ERROR FACTOR: 1.2  REPAIR TIME: 10 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1064. Cum.oper.time 73.7E+6 hours. 98 failures. "All modes" incl 1) external leak, 2) fail to operate, 3) fail to open, 4) fail closed, 5) out of calibration, 6) unspec. 6) dominant, 3) & 4) negligible (1 fail).

VWZAE  valve pressure regulating 2-6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec : 2.9E-6/hr  REPAIR TIME: 1.3 hours
Comment: reference: R/M data base FM see comment angle valve.

VWXCF  valve pressure regulating valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 1.1E-7/hr  95%: 1.9E-7/hr  5%: 6.8E-8/hr  ERROR FACTOR: 1.7  REPAIR TIME: 5 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1064. Cum.operating time 73.7E+6 hours. 8 failures. Number of demands in operating time is not known. Failure rate for this FM is order of magnitude higher than for "fail to open".

VWXYF  valve pressure regulating valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 2.7E-7/hr  95%: 3.9E-7/hr  5%: 1.9E-7/hr  ERROR FACTOR: 1.4  REPAIR TIME: 8 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1064. Cum.operating experience 73.7E+6 hours. 20 failures.

VRBDV  valve primary relief valve BWR
Component boundary: valve body and internals, operating mechanism  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: premature open
FAILURE RATE OR PROBABILITY mean : 3.5E-6/hr  95%: 4.9E-6/hr  5%: 2.3E-6/hr
Comment: W/o command faults. With command faults 3.9E-6/hr Includes all BWR safety relief valves (ADS and ordinary relief valves).
VRBEV valve primary relief valve BWR
Component boundary: valve body and internals, operating mechanism Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to reset
FAILURE RATE OR PROBABILITY mean: 3.1E-3/d 95%: 4.7E-3/d 5%: 2.1E-3/d
Comment: See comment relief failure to open. Standby hourly rate 3.0E-6/hr. W/o command faults. With command faults 3.2E-3/d. Standby hourly rate with command faults 3.2E-6/hr.

VRBOV valve primary relief valve BWR
Component boundary: valve body and internals, operating mechanism Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean: 8.9E-3/d 95%: 1.1E-2/d 5%: 6.8E-3/d
Comment: Incl. all BWR safety-relief vlv(ADS and ordinary relief). W/o command. W command 1.1E-2/d. No. of demands is 1 test and operational demand equal to tot. no. of forced and manual scrams. Rate 8.7E-6/hr stdby.

VRAAE valve relief
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY rec: 2.3E-6/hr high: 2.4E-6/hr low: 1.2E-6/hr REPAIR TIME: .6 hours
Comment: This values are composite of different sources and different types and sizes of relief valves. Valve operators (if any) are not identified.

VRADW valve relief
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: premature open
FAILURE RATE OR PROBABILITY median: 1.0E-5/hr 95%: 3.0E-5/hr 5%: 3.0E-6/hr ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear, industrial(SRS) and mil. experience and data
Comment:

VRAOW valve relief
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY median: 1.0E-5/d 95%: 3.0E-5/d 5%: 3.0E-6/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear, industrial(SRS) and mil. experience and data
Comment:
VRDCH valve relief main steam atmospheric relief valve
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY mean : 3.0E-3/d  95%: 7.0E-3/d  5%: 3.6E-4/d
Source: Old PWR  Ultimate source: generic data updated with paint operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 199 demands, 1 failure.

VR68F valve relief & safety diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 1.5E-7/hr  95%: 4.6E-7/hr  5%: 5.7E-8/hr  ERROR FACTOR: 2.4  REPAIR TIME: 26 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.242. Cumulative operating time 13.8E+6 hours. 2 failures.

VR6EF valve relief & safety diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to reseat
FAILURE RATE OR PROBABILITY mean : 1.5E-7/hr  95%: 4.6E-7/hr  5%: 5.7E-8/hr  ERROR FACTOR: 2.4  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.242. Cumulative operating time 13.8E+6 hours. 2 failures. Number of opening in cumulative operating time is not known.

VR6AF valve relief & safety diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 2.6E-6/hr  95%: 3.4E-6/hr  5%: 2.0E-6/hr  ERROR FACTOR: 1.3  REPAIR TIME: 14 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.242. Cumulative operating time 13.8E+6 hours. 36 failures. "All modes" incl:1) fail to reseat, 2) external, 3) internal leak, 4) out of calibr. 5) unspecified. 5) is dominant, all other about equal.

VR88F valve relief & safety diameter larger than 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 3.7E-7/hr  95%: 1.2E-6/hr  5%: 1.5E-7/hr  ERROR FACTOR: 2.4  REPAIR TIME: 8 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.96. Cumulative operating time 5.5E+6 hours. 2 failures.
VRBAF
valve relief & safety diameter larger than 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 1.8E-6/hr 95%: 3.1E-6/hr 5%: 1.1E-6/hr ERROR FACTOR: 1.6 REPAIR TIME: 8 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.96. Cum. operating time 5.5E+6 hours. 10 failures. "All modes" incl: 1) internal leak, 2) out of calibration, 3) unspecified. 1) & 2) identical, 3) 3 times larger.

VR2BF
valve relief & safety diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean: 2.4E-7/hr 95%: 3.3E-7/hr 5%: 1.7E-7/hr ERROR FACTOR: 1.4 REPAIR TIME: 7 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.1667. Cumulative component operating time 109E+6 hours. 26 failures.

VR2EF
valve relief & safety diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to reseat
FAILURE RATE OR PROBABILITY mean: 3.4E-8/hr 95%: 8.0E-8/hr 5%: 2.3E-8/hr ERROR FACTOR: 1.8 REPAIR TIME: 7 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.1667. Cumulative component operating time 109E+6 hours. No. of failures 4. Number of opening in cumulative time is not known.

VR2AF
valve relief & safety diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 9.5E-7/hr 95%: 1.1E-6/hr 5%: 8.1E-7/hr ERROR FACTOR: 1.2 REPAIR TIME: 7 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.1667. Cum. operating time 109E+6 hours. 103 failures. "All modes" incl: 1) fail to reseat, 2) external, 3) internal leak, 4) out of calibration, 5) unspecified. 5) dominant, 1), 2), and 4) significantly lower.

VRAEI
valve relief valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close, given open
FAILURE RATE OR PROBABILITY mean: 2.0E-2/d ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:
VRAOI valve relief valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 3.0E-4/d  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:

VSADDe valve safety
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: premature open
FAILURE RATE OR PROBABILITY  rec : 3.0E-6/hr

VSADDe valve safety
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open
FAILURE RATE OR PROBABILITY  rec : 4.0E-3/cy

VSADU valve safety valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious opening
FAILURE RATE OR PROBABILITY  mean : 2.0E-6/hr  95%: 1.2E-5/hr  REPAIR TIME: 4 hours
Source: Swedish Rel. data book, tbl.21  Ultimate source: plant operating experience(7 BWR plants), ATV reports, LERs
Comment: Total pop.139. Operational time 404E+4.No of failures 7. Critical failures reported on 4 plants. a=0.102; b=50300
Leakage generally equals spurious opening (conservative approach)

VWVAE valve vent 3/4 inch, float operated, tank vent
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 3.1E-6/hr  REPAIR TIME: 1.2 hours
Comment: reference: Corps of Engineers(HND) R/M Data Base, Ground Stationary Equipment, Re.No.16,04/12/73.
VARDH valve air operated all systems except raw water return line
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean : 1.2E-7/hr 95%: 2.7E-7/hr 5%: 1.4E-8/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-7/hr. Operating experience 3E+6 hours of operation, no failures.

VAPDH valve air operated purge isolation valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer open
FAILURE RATE OR PROBABILITY mean : 2.0E-7/hr 95%: 5.0E-7/hr 5%: 1.5E-8/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-7/hr. Operating experience 4.7E+5 hours of operation, no failures.

VAPEN valve air operated purge isolation valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY mean : 2.3E-3/d 95%: 4.4E-3/d 5%: 8.4E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.5E-3/d. Operating experience 756 demands, 3 failures.

VAPOH valve air operated purge isolation valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY mean : 1.3E-3/d 95%: 2.4E-3/d 5%: 4.6E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.5E-3/d. Operating experience 756 demands, 1 failure.

VAQDH valve air operated raw water return line
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean : 5.5E-6/hr 95%: 1.2E-5/hr 5%: 7.7E-7/hr
Source: Old PWR Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 2.7E-7/hr. Operating experience 1.4E+5 hours of operation, 3 failures.
VAZEH valve air operated turbine stop valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY  mean : 1.1E-4/d  95%: 2.2E-4/d  5%: 3.0E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.3E-4/d. Operating experience 1680 demands, no failures.

VAIH valve air operated vent isolation valve (annulus ventilation)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer open
FAILURE RATE OR PROBABILITY  mean : 2.2E-7/hr  95%: 5.5E-7/hr  5%: 1.6E-8/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-7/hr. Operating experience 2.6E+5 hours of operation, no failures.

VAIEH valve air operated vent isolation valve (annulus ventilation)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY  mean : 1.2E-3/d  95%: 2.2E-3/d  5%: 2.8E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.5E-3/d. Operating experience 362 demands, no failures.

VAIOH valve air operated vent isolation valve (annulus ventilation)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY  mean : 1.1E-2/d  95%: 2.0E-2/d  5%: 4.0E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.5E-3/d. Operating experience 362 demands, 6 failures.

VABCV valve air operated BWR (ESF systems valves only)
Component boundary: valve body & internals, operator, funct. accessories (limit, torque sw)  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY  mean : 2.6E-3/d  95%: 5.2E-3/d  5%: 1.1E-3/d
Comment: With command faults. No failures recorded in w/o command faults category, 95% confidence bound is 1.3E-3/d. Standby hourly rate with command 1.2E-6/hr, w/o command (95%) 5.9E-7/hr.
VAWCV valve air operated PWR (ESF systems valves only)
Component boundary: valve body & interiors, operator, functional accessories (e.g., limit sw)
Operating mode: all
Operating environment: normal
Generic failure mode: fail to change position
Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY
mean: 1.2E-3/d
95%: 2.2E-3/d
5%: 6.0E-4/d
Source: NUREG 1363 (1982) (pg. 422)
Ultimate source: US plants LER reports evaluation
Comment: W/o command faults. With command faults 2.1E-3/d. Standby hourly failure rate w/o command 5.6E-7/hr, with command 9.8E-7/hr.

VAEVY valve air operated PWR + BWR (ESF systems valves only)
Component boundary: valve body & internals, operator, functional access (limit, torque sw)
Operating mode: all
Operating environment: normal
Generic failure mode: leakage/external leak
Original failure mode: leak externally
FAILURE RATE OR PROBABILITY
mean: 1.0E-7/hr
95%: 3.1E-7/hr
5%: 1.8E-8/hr
Source: NUREG 1363 (1982) (pg. 430)
Ultimate source: US plants LER reports evaluation
Comment: Overall rate. BUR rate is twice larger than PWR rate.

VAAEH valve air operated all systems
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: fail to close
Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY
mean: 1.2E-3/d
95%: 1.8E-3/d
5%: 6.9E-4/d
Source: Old PUR
Ultimate source: generic data updated with plant specific operating experience
Comment: Generic mean 1.5E-3/d. Operating experience 4970 demands, 6 failures.

VAAOH valve air operated all systems
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: fail to open
Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY
mean: 8.4E-4/d
95%: 1.4E-3/d
5%: 3.5E-4/d
Source: Old PUR
Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.5E-3/d. Operating experience 4970 demands, 3 failures.

VATBF valve air operated butterfly diameter larger than 24 inches
Component boundary: detail n/a
Operating mode: all
Operating environment: normal
Generic failure mode: internal leak
Original failure mode: internal leak
FAILURE RATE OR PROBABILITY
mean: 1.6E-7/hr
95%: 7.6E-7/hr
5%: 5.7E-8/hr
ERROR FACTOR: 2.8
Source: HWR data
Ultimate source: HWR operating experience
Comment: Pop.70.Cum.operating time 632E+4 hours. No.of failures 1. Data based on experience with control valves.
VATAF  
valve air operated butterfly diameter larger than 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 3.2E-5/hr  95%: 3.6E-5/hr  5%: 2.8E-5/hr  ERROR FACTOR: 1.1  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.70.Cum.operating time 623E+4 hours.No of failures 199.Failure mode include:1) fail to operate,2) external,3) internal leak,4) fault indication,5) plugged,6) unspecified.Contrib.of 3)&5) negligible.

VATCF  
valve air operated butterfly diameter larger than 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY  mean : 7.2E-6/hr  95%: 9.3E-6/hr  5%: 5.7E-6/hr  ERROR FACTOR: 1.3  REPAIR TIME: 6 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.70.Cum.operating time 623E+4 hours.No.of failures 45.No.of demands not known.Data based on experience with control valves.FM include actuator failures but not air supply to acuator.

VATQF  
valve air operated butterfly diameter larger than 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: plug  Original failure mode: plugged
FAILURE RATE OR PROBABILITY  mean : 1.6E-7/hr  95%: 7.6E-7/hr  5%: 5.7E-8/hr  ERROR FACTOR: 2.8  REPAIR TIME: 12 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.70.Cum.operating time 623E+4 hours.No.of failures 1. Data based on experience with control valves.

VATYF  
valve air operated butterfly diameter larger than 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY  mean : 1.1E-5/hr  95%: 1.3E-5/hr  5%: 8.7E-6/hr  ERROR FACTOR: 1.2  REPAIR TIME: 2 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.70.Cum.operating time 623E+4 hours.No.of failures 66. Data based on experience with control valves.

VATDW  
valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY  median: 3.0E-7/hr  95%: 1.0E-6/hr  5%: 1.0E-7/hr  ERROR FACTOR: 3
Source: WASH 1400  (table III 4-1)  Ultimate source: ultimate source not known(sources presenting plug per demand)
Comment: Plug probabilities are given per demand and per hour since phenomena is generally time dependant, but plugged conditions may be discovered only upon demand. See FM comment air valve/demand.
VAACB valve air operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 1.0E-5/hr max: 5.0E-5/hr min: 2.0E-7/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment:

VAACG valve air operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to open or to close
FAILURE RATE OR PROBABILITY mean: 4.3E-5/hr ERROR FACTOR: 23
Source: German Risk Study (pg P3-76) Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources. Compared with other valve types failure rate seems to be too high

VAACI valve air operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 3.0E-3/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

VAACJ valve air operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY mean: 1.0E-3/d ERROR FACTOR: 3
Source: NUREG 4550, Vol I, Tbl. VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: Generic value developed in Station Blackout Study (NUREG/CR-3226). Two types of failures are included in the failure rate: valve hardware faults (1.0E-3) and command circuit faults (1.0E-4).

VAACO valve air operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 1.6E-3/d 95%: 3.1E-3/d 5%: 3.2E-4/d
Source: Oconee NPP PRA (tbl. b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, PWR air-op valves, failure on demand, w/o command 80%/20% ratio = 10. Operating experience; 1349 demands, 3 failures.
VAACU valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean : 6.0E-6/hr
Source: Sizewell B (PWR/RX312 pg.8)  Ultimate source: assessed from nuclear experience and generic data
Comment: Assessment based on W data item and WASH 1400 data(failure cited is not one which appears in WASH 1400). For monthly testing, peak probability is 4.3E-3/d, what is pessimistic compared to W-1400.

VAACW valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  median: 3.0E-4/d  95%: 1.0E-3/d  5%: 1.0E-4/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Failure to operate includes changing state from open to closed or closed to open.

VAACZ valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate on demand
FAILURE RATE OR PROBABILITY  mean : 1.4E-3/d
Source: Zion NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Priors: NUREG 1363 air operated valve (PWR), fail to operate (mean) and WASH 1400 air operated valve, fail to operate (distrib.)
Operating experience: 1540 demands, 3 failures.

VAADO valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 8.0E-7/hr  95%: 2.3E-6/hr  5%: 3.9E-8/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: WASH 1400, air-op valves, fail to remain open. 5% = 20%; 95% = 80%. Per demand rate converted to hrly rate assuming 1 d.in 45 days.
Operating experience: 1.94E+5 hours of operation, 1 failure.

VAADW valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY  median: 1.0E-4/d  95%: 3.0E-4/d  5%: 3.0E-5/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from nuclear experience (incl.test & research reactors)
Comment: Failure to remain open refers to reduction of flow to unusable level due to foreign material or gate failure. Not included in data is inadvertent or false signal driving valve closed.
VAADZ valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed, plugged
FAILURE RATE OR PROBABILITY mean : 1.1E-7/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Prior:WASH 1400, air operated valve, failure to remain open (plug). 1 demand in 45 days used to convert to hourly rate. Operating experience: 2.13E+6 hours of operation, no failures.

VAATW valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: rupture  Original failure mode: rupture
FAILURE RATE OR PROBABILITY median: 1.0E-8/hr  95%: 1.0E-7/hr  5%: 1.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from US nuclear experience
Comment:

VAAYJ valve air operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: fails from plugging
FAILURE RATE OR PROBABILITY mean : 4.0E-5/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1,tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: Value is based on NRC LER data summary (1.0E-7/hr) and assuming monthly system test (720 hrs).

VASCW valve air operated general (BWR application)
Component boundary: detail n/a(generally excludes operator)  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY rec : 3.0E-3/cy

VASYE valve air operated general (BWR application)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leakage
FAILURE RATE OR PROBABILITY rec : 2.0E-7/hr
VAWCE valve air operated general (PWR application)
Component boundary: detail n/a (generally excludes driver) Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY $: 2.0E-3/cy$

VAWYE valve air operated general (PWR application)
Component boundary: detail n/a (generally excludes driver) Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leakage
FAILURE RATE OR PROBABILITY $: 7.0E-8/hr$

VAKAF valve air operated globe diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 4.0E-6/hr 95%: 4.8E-6/hr 5%: 3.4E-6/hr ERROR FACTOR: 1.2 REPAIR TIME: 10 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.343. Cum.operating time 22.4E+6 hours. 34 failures. Number of demands in operational time is not known. FM include actuator failures, but not air supply. Based on experience with control valves.

VAKCF valve air operated globe diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 1.5E-6/hr 95%: 2.0E-6/hr 5%: 1.1E-6/hr ERROR FACTOR: 1.3 REPAIR TIME: 11 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.343. Cum.operating time 22.4E+6 hours. 34 failures. Number of demands in operational time is not known. FM include actuator failures, but not air supply. Based on experience with control valves.

VAKYF valve air operated globe diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 6.7E-7/hr 95%: 1.0E-6/hr 5%: 4.5E-7/hr ERROR FACTOR: 1.5 REPAIR TIME: 11 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.343. Cum.operating time 22.4E+6 hours. 15 failures. Based on experience with control valves.
VAL8F valve air operated globe diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean: 3.4E-7/hr 95%: 5.7E-7/hr 5%: 2.6E-7/hr ERROR FACTOR: 1.6 REPAIR TIME: 27 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.420. Cum.operating time 32.1E+6 hours. 11 failures. Data based on experience with control valves.

VALAF valve air operated globe diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 2.4E-6/hr 95%: 3.3E-6/hr 5%: 2.3E-6/hr ERROR FACTOR: 1.2 REPAIR TIME: 10 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.420. Cum.operating time 32.1E+7 hours. 78 failures. "All modes" incl: 1) fail to operate, 2) external, 3) internal leak, 4) unspecified. About equal contribution. Data based on experience with control valves.

VALCF valve air operated globe diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean: 9.9E-7/hr 95%: 1.3E-6/hr 5%: 7.5E-7/hr ERROR FACTOR: 1.3 REPAIR TIME: 5 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.420. Cum.operating time 32.1E+6 hours. 31 failure. No. of demand in operational time is not known. FM include actuator failures, but not power supply to actuator. Data based on experience with control valves.

VALYF valve air operated globe diameter less than 2 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean: 4.0E-7/hr 95%: 6.4E-7/hr 5%: 2.6E-7/hr ERROR FACTOR: 1.5 REPAIR TIME: 11 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.420. Cum.operating time 32.1E+6 hours. 13 failures. Data based on experience with control valves.

VAHEH valve air operated turbine governor valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY mean: 1.1E-4/d 95%: 2.2E-4/d 5%: 3.0E-5/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.3E-4/d. Operating experience 1680 demands, no failures.
VWAE

Valve composite by design

Component boundary: detail n/a \ Operating mode: all \ Operating environment: normal

Generic failure mode: all modes \ Original failure mode: all modes

Failure Rate or Probability rec.: 2.8E-6/hr \ high: 3.2E-3/hr \ low: 3.0E-8/hr \ Repair Time: 1.4 hours

Source: IEEE 500 (1984) pg.1041 \ Ultimate source: expert judgement (delphi procedure) and experience

Comment: This value is composite of all data on valves, grouped by design characteristic. It is given for illustrative purposes.

Per cycle (demand) rate is 7.6E-5/cy. FM see comment angle valve.

VEACJ

Valve explosive operated general

Component boundary: detail n/a \ Operating mode: all \ Operating environment: normal

Generic failure mode: fail to change position \ Original failure mode: fails to operate

Failure Rate or Probability mean: 3.0E-3/d \ Error Factor: 10

Source: NUREG 4550, Vol.1, tbl.VIII.1-2 \ Ultimate source: assessed from several nuclear data sources

Comment: The same value as for motor operated valves. Values developed in Station Blackout Study were used. Two types of failure are included: valve hardware (5.0E-4) and command circuits faults (2.5E-4).

VEAYJ

Valve explosive operated general

Component boundary: detail n/a \ Operating mode: all \ Operating environment: normal

Generic failure mode: leakage/external leak \ Original failure mode: fail from plugging

Failure Rate or Probability mean: 4.0E-5/d \ Error Factor: 3

Source: NUREG 4550, Vol.1, tbl.VIII.1-2 \ Ultimate source: assessed from several nuclear data sources

Comment: Values assumed to be the same as for motor operated valves. Value is based on NRC LER data summary (1.0E-7/hr) and assuming monthly test interval.

VHACJ

Valve hydraulic operated general

Component boundary: detail n/a \ Operating mode: all \ Operating environment: normal

Generic failure mode: fail to change position \ Original failure mode: fails to operate

Failure Rate or Probability mean: 1.0E-3/d \ Error Factor: 3

Source: NUREG 4550, Vol.1, tbl VIII.1-2 \ Ultimate source: assessed from several nuclear data sources

Comment: The same values as for air operated were assumed. Two types of failure included: valve hardware faults (1.0E-3/d) and command circuit faults (1.0E-4).

VHAYJ

Valve hydraulic operated general

Component boundary: detail n/a \ Operating mode: all \ Operating environment: normal

Generic failure mode: leakage/external leak \ Original failure mode: fail from plugging

Failure Rate or Probability mean: 4.0E-5/d \ Error Factor: 3

Source: NUREG 4550, Vol.1, tbl.VIII.1-2 \ Ultimate source: assessed from several nuclear data sources

Comment: Values assumed to be the same as for air operated valves. Value is based on NRC LER data summary (1.0E-7/hr) assuming monthly test interval.
VXADH valve manual
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean : 1.7E-8/hr 95%: 4.3E-8/hr 5%: 1.4E-9/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.2E-8/hr. Operating experience 1.8E+7 hours of operation, no failures.

VXEYV valve manual PWR + BWR (ESF systems valves only)
Component boundary: valve body and interiors, operating mechanism Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leakage
FAILURE RATE OR PROBABILITY mean : 2.2E-8/hr 95%: 5.7E-8/hr 5%: 5.9E-9/hr
Comment: Overall data PWR and BWR about equal.

VXECV valve manual PWR + BWR (ESF systems valves only)
Component boundary: valve body and interiors, operating mechanism Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 6.3E-5/d 95%: 1.6E-4/d 5%: 2.1E-5/d
Comment: Overall data PWR and BWR about equal. Standby hourly rate 2.9E-8/hr.

VXTDH valve manual butterfly all systems except HVAC
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean : 3.1E-8/hr 95%: 9.8E-8/hr 5%: 1.5E-9/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.2E-8/hr. Operating experience 2.2E+6 hours, no failures.

VXGAF valve manual gate diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 2.4E-6/hr 95%: 2.9E-6/hr 5%: 2.0E-6/hr ERROR FACTOR: 1.2 REPAIR TIME: 10 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.520.Cum.operating time 34.6E+6 hours.84 failures."All modes" incl:1)fail to operate,2)external,3)internal leak,4)faulty indic.
5)plugged,6)unspecified. 2)is dominant,5) 40 times lower.
VXGCF  valve manual gate diameter between 12 and 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 4.3E-7/hr  95%: 6.7E-7/hr  5%: 2.9E-7/hr  ERROR FACTOR: 1.5
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.520. Cumulative operating time 34.6E+6 hours. 15 failures. Number of demand per operational time is not known.

VXGYF  valve manual gate diameter between 12 and 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 1.4E-6/hr  95%: 1.8E-6/hr  5%: 1.1E-6/hr  ERROR FACTOR: 1.3
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.520. Cumulative operating time 34.6E+6 hours. 49 failures.

VXHBF  valve manual gate diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 1.0E-7/hr  95%: 1.5E-7/hr  5%: 8.0E-8/hr  ERROR FACTOR: 1.3
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop. 3546. Cum.operating experience 2.5E+8 hours. 26 failures.

VXHAF  valve manual gate diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.2E-6/hr  95%: 1.3E-6/hr  5%: 1.0E-6/hr  ERROR FACTOR: 1.1
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop 3546. Cum.operating time 2.5E+8 hours. 278 failures. "All modes" incl:1)external,2)internal leak,3)fail to operate,4)plugged,5) unspecified. 1) is dominant, 4) is negligible(1 failure only)

VXHCF  valve manual gate diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 1.3E-7/hr  95%: 1.6E-7/hr  5%: 9.1E-8/hr  ERROR FACTOR: 1.3
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.3546. Cum.operating time 2.5E+8 hours. 30 failures. Number of demands per operating time is not known.
VXHYF  valve manual gate diameter between 2 and 6 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY  mean : 6.4E-7/hr  95%: 7.3E-7/hr  5%: 5.6E-7/hr  ERROR FACTOR: 1.1
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.3546. Cumulative component operating time 2.5E+8 hours. No. of failures 160.

VXIAF  valve manual gate diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 2.4E-6/hr  95%: 2.6E-6/hr  5%: 2.1E-6/hr  ERROR FACTOR: 1.1
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1179. Cumulative operating time 8.2E+6 hours 199 failures. "All modes incl: 1) external, 2) internal leak, 3) fail to operate, 4) faulty indic. 5) plugged, 6) unspecified. 1) is dominant, 3), 4) and 5) 25 times lower.

VXICF  valve manual gate diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY  mean : 2.2E-7/hr  95%: 3.2E-7/hr  5%: 1.5E-7/hr  ERROR FACTOR: 1.4
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1179. Cumulative operating time 8.2E+6 hours 18 failures. Number of demands per operational time in not known.

VXIYF  valve manual gate diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY  mean : 1.5E-6/hr  95%: 2.1E-6/hr  5%: 1.3E-6/hr  ERROR FACTOR: 1.2
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1179. Cumulative component operating time 8.2E+6 hours. No. of failures 122.

VXSAF  valve manual gate diameter less than 2 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  mean : 5.4E-7/hr  95%: 5.7E-7/hr  5%: 5.1E-7/hr  ERROR FACTOR: 1.1
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.19351. Cumulative operating time 1.36E+9 hours 707 failures. "All modes" incl: 1) external, 2) internal leak, 3) fail to operate, 4) plugged, 5) unspecified. 1) and 5) dominant, 4) negligible.
VXSCF  valve manual gate diameter less than 2 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY  mean: 3.3E-8/hr  95%: 4.2E-8/hr  5%: 2.6E-8/hr  ERROR FACTOR: 1.3  
REPAIR TIME: 2 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop.19351. Cum.operating time 1.3E+9 hours. 43 failures. Number of demands per operating time is not known.

VXSYF  valve manual gate diameter less than 2 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: leakage/external leak  Original failure mode: external leak  
FAILURE RATE OR PROBABILITY  mean: 2.2E-7/hr  95%: 2.4E-7/hr  5%: 1.9E-7/hr  ERROR FACTOR: 1.1  
REPAIR TIME: 3 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop.19351. Cum.operating time 1.3E+9 hours. 286 failures.

VXACB  valve manual general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY  mean: 2.0E-7/hr  max: 1.0E-6/hr  min: 8.0E-8/hr  
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data  
Comment: Failure to operate is dominated by human error. Rate is based on one actuation per month.

VXACG  valve manual general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: fail to open or to close  
FAILURE RATE OR PROBABILITY  mean: 4.7E-6/hr  ERROR FACTOR: 12  
Source: German Risk Study (pg.F3-79)  Ultimate source: generic data and operating experience  
Comment: Both generic and specific sources were combined for this failure rate.

VXACI  valve manual general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY  mean: 1.0E-4/d  ERROR FACTOR: 3  
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion  
Comment: Failure to operate is dominated by human error. Hourly rate 3.0E-7 (EF 10) is based on one actuation per month.
VXADO valve manual general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 8.9E-8/hr  95%: 2.4E-7/hr  5%: 4.8E-9/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, failure of internals of manual valves. Operating experience: 3.09E+6 hours of operation, 1 failure. 95%/5% ratio is 100, indicating high degree of uncertainty.

VXADW valve manual general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY median: 1.0E-4/d  95%: 3.0E-4/d  5%: 3.0E-5/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from US nuclear experience (including test & research R)
Comment: Failure to remain open refers to reduction of flow to unusable level due to foreign material or age failure.

VXAYJ valve manual general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: fails from plugging
FAILURE RATE OR PROBABILITY mean : 4.0E-5/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1 tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: Value based on NRC LER data summaries (1.0E-7/hr) assuming monthly test interval (720 hrs).

VXBCE valve manual general (BWR application)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failed to operate
FAILURE RATE OR PROBABILITY rec : 6.0E-5/cy
Comment: Reference EGG-EA-5B16 82.Data Summaries of LER of Valves at US Commercial NPP

VXBYE valve manual general (BWR application)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leakage
FAILURE RATE OR PROBABILITY rec : 3.0E-8/hr
Source: IEEE 500 (1984) pg.1019  Ultimate source: expert opinion aggregation(delphi procedure) & operating experience
Comment: Reference EGG-EA-5B16 82.Data Summaries of LER of Valves at US Commercial NPP.
VXPCE  valve manual general (PWR application)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failed to operate
FAILURE RATE OR PROBABILITY  rec  : 7.0E-5/cy
Comment:

VXPYE  valve manual general (PWR application)
Component boundary: detail n/a (generally excludes operator)  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leakage
FAILURE RATE OR PROBABILITY  rec  : 2.0E-8/hr
Source: IEEE 500 (1984) pg.1018  Ultimate source: expert judgement aggregation (delphi method) and experience
Comment:

VMCCZ  valve motor operated  Chemical and volume control system valves
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate on demand
FAILURE RATE OR PROBABILITY  mean  : 3.7E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Priors: NUREG 1363, MOV+remote(PWR)(w/o command) fail to operate(M) and WASH 1400 MOV, fails to operate (distrib).
Operating experience: 1720 demands, 7 failures.

VMBCO  valve motor operated  all except condenser circulating water
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean  : 6.4E-3/d  95%: 7.7E-3/d  5%: 4.5E-3/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience

VMJCZ  valve motor operated  all except for use in CVCS and CCS systems
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate on demand
FAILURE RATE OR PROBABILITY  mean  : 1.6E-3/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Priors: NUREG 1363 MOV+remote(PWR)(w/o command) fail to operate(M) and WASH 1400 failed to operate (distrib.).
Operating experience: 11310 demands, 14 failures.
VMDCO valve motor operated condenser circulating water valves
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean: 1.0E-1/d 95%: 1.6E-1/d 5%: 2.7E-2/d
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, failure of MOV and remote operated on demand. Operating experience: 30 demands, 5 failures.

VMECZ valve motor operated containment spray system valves
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to operate on demand
FAILURE RATE OR PROBABILITY mean: 5.7E-3/d
Source: ZION NPP PSS (tbl.1.5.1-1) Ultimate source: generic data updated with plant operating experience
Comment: Prior: NUREG 1363 MOV+remote (PWR)(w/o command), fail to operate (M) and WASH 1400 MOV, fails to operate (distrib.).
Operating experience: 1647 demands, 10 failures.

VMIEH valve motor operated main steam isolation valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY mean: 4.3E-3/d 95%: 7.4E-3/d 5%: 6.9E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.3E-3/d. Operating experience 714 demands, no failures.

VMICV valve motor operated BWR (ESF systems valves only)
Component boundary: valve body and its internal parts, motor, functional accessories Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean: 2.6E-1/d 95%: 2.6E-1/d 5%: 1.6E-1/d
Comment: W/o command faults. With command 9.6E-3/d. Standby hourly failure rate: w/o 3.1E-6/hr; with 4.4E-6/hr. LER rates from 'unknown remote and MOV' what better represent MOV population.

VMICG valve motor operated MSIV (FF-Schnellschlusschieber) gate
Component boundary: main valve without pilot valve Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY median: 6.0E-3/d ERROR FACTOR: 4
Source: German Risk Study (tb.F3.7-1) Ultimate source: operating experience
Comment: Bases for failure rate is 112 operating demands without failure.
VMHCV valve motor operated PWR (ESF system valves only)
Component boundary: valve body & internals,motor,functional accessories(limit switch) Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean : 4.1E-3/d 95%: 4.9E-3/d 5%: 3.4E-3/d
Comment: W/o command faults. With command faults 6.2E-3/d. Standby rate 1.9E-6/hr. LER rate from 'unknown remote and motor operated' what better represent MOV population.

VMHQV valve motor operated PWR + BWR (ESF systems valves only)
Component boundary: valve body & internals,motor,functional accessories(limit switch) Operating mode: all Operating environment: normal
Generic failure mode: plug Original failure mode: plugged
FAILURE RATE OR PROBABILITY mean : 8.1E-9/hr 95%: 3.8E-8/hr 5%: 4.8E-10/hr
Comment: Overall rate. LER rate from 'unknown remote and MOV' what better represent MOV population. W/o command faults. With command faults 7.3E-8/hr.

VMHYV valve motor operated PWR + BWR (ESF systems valves only)
Component boundary: valve body & interiors,motor,functional accessories(limit switch) Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: leak externally
FAILURE RATE OR PROBABILITY mean : 1.4E-7/hr 95%: 2.1E-7/hr 5%: 8.7E-8/hr
Comment: LER rate from 'unknown remote and MOV' what better represent MOV population. W/o command faults. With command faults 7.3E-8/hr.

VMSBF valve motor operated butterfly diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 2.5E-7/hr 95%: 7.8E-7/hr 5%: 1.0E-7/hr ERROR FACTOR: 2.3 REPAIR TIME: 14 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.95.Cum.operating time 8E+6 hours.No.of failures 2.Data based on experience with isolating valves with either electric or pneumatic operator.

VMSAF valve motor operated butterfly diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 4.9E-6/hr 95%: 6.3E-6/hr 5%: 3.8E-6/hr ERROR FACTOR: 1.3 REPAIR TIME: 30 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.95.Cum.operating time 8E+6 hours.No.of failures 39.Failure mo incl:1) fail to operate, 2) external leak, 3) internal leak, 4) faulty indication, 5) unspecified. Failure rate dominated by 1) and 5).
<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Description</th>
<th>Component Boundary</th>
<th>Operating Mode</th>
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<th>Generic Failure Mode</th>
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<th>Failure Rate Or Probability Mean</th>
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<th>Comment</th>
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<tbody>
<tr>
<td>VMSCF</td>
<td>Valve motor operated butterfly diameter between 12 and 24 inches</td>
<td></td>
<td>all</td>
<td>normal</td>
<td>fail to change position</td>
<td>fail to operate</td>
<td>2.6E-6/hr</td>
<td>3.8E-6/hr</td>
<td>1.9E-6/hr</td>
<td>1.4</td>
<td>10 hours</td>
<td>HWR data</td>
<td>WRU operating experience</td>
<td>pop.95 cum. operating time 8E+6 hours. No. of failures 21. No. of demands not known. Failure mode &quot;fail to operate&quot; include actuator failure but not loss of power. Data from isolation valves.</td>
</tr>
<tr>
<td>VMSYF</td>
<td>Valve motor operated butterfly diameter between 12 and 24 inches</td>
<td></td>
<td>all</td>
<td>normal</td>
<td>leakage/external leak</td>
<td>external leak</td>
<td>1.2E-7/hr</td>
<td>6.4E-7/hr</td>
<td>4.6E-8/hr</td>
<td>3.1</td>
<td>4 hours</td>
<td>HWR data</td>
<td>WRU operating experience</td>
<td>pop.95 cum. operating time 8E+6 hours. No. of failures 1. Data based on experience with isolating valves with either pneumatic or electric valve operator.</td>
</tr>
<tr>
<td>VMUAF</td>
<td>Valve motor operated butterfly diameter between 2 and 6 inches</td>
<td></td>
<td>all</td>
<td>normal</td>
<td>all modes</td>
<td>all modes</td>
<td>7.4E-7/hr</td>
<td>1.3E-7/hr</td>
<td>4.3E-7/hr</td>
<td>1.7</td>
<td>15 hours</td>
<td>HWR data</td>
<td>WRU operating experience</td>
<td>Failure mode &quot;all modes&quot; include 1) fail to operate, 2) external leak, 3) faulty indication, 4) unspecified. Failure rate is dominated by 3) and 4). Total pop. 157. Oper. time 10.80E+6 hrs. 8 failures.</td>
</tr>
<tr>
<td>VMUCF</td>
<td>Valve motor operated butterfly diameter between 2 and 6 inches</td>
<td></td>
<td>all</td>
<td>normal</td>
<td>fail to change position</td>
<td>fail to operate</td>
<td>9.1E-8/hr</td>
<td>4.3E-7/hr</td>
<td>3.4E-8/hr</td>
<td>2.7</td>
<td>1 hour</td>
<td>HWR data</td>
<td>WRU operating experience</td>
<td>pop.157. Cum. operating time 1080E+4 hours. 1 failure. No. of demands in time not known. Data based on experience with isolating valves (elecr.or pneum. operator). FM. incl. failure of actuator, w/o comm.</td>
</tr>
<tr>
<td>VMUYF</td>
<td>Valve motor operated butterfly diameter between 2 and 6 inches</td>
<td></td>
<td>all</td>
<td>normal</td>
<td>leakage/external leak</td>
<td>external leak</td>
<td>9.1E-8/hr</td>
<td>4.3E-7/hr</td>
<td>3.4E-8/hr</td>
<td>2.7</td>
<td>1 hour</td>
<td>HWR data</td>
<td>WRU operating experience</td>
<td>Data based on experience with isolating valves with either electric or pneumatic operator. Pop. 157. Cum. operating time 10.80E+6 hours. No. of failures 1.</td>
</tr>
</tbody>
</table>
VMT8F valve motor operated butterfly diameter between 6 and 12 inches

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 7.0E-7/hr  95%: 1.2E-6/hr  5%: 4.2E-7/hr  ERROR FACTOR: 1.6  REPAIR TIME: 5 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.165.Cum.operating time:12.95E+6 hours.No.of failures 9. Data based on experience with isolating valves with either electric or pneumatic operator.

VMTAF valve motor operated butterfly diameter between 6 and 12 inches

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 6.8E-6/hr  95%: 8.2E-6/hr  5%: 5.8E-6/hr  ERROR FACTOR: 1.2  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: WRU operating experience
Comment: failure mode"all modes" include:1)fail to operate,2)external leak,3)internal leak,4)faulty identification,5) unspecified. Failure rate is dominated by 1) and 5). Tot.pop.165.12.9E+6op.hrs.89 fail.

VMTCF valve motor operated butterfly diameter between 6 and 12 inches

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 3.6E-6/hr  95%: 4.6E-6/hr  5%: 2.9E-6/hr  ERROR FACTOR: 1.3  REPAIR TIME: 3 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.165.Cum.operating time:12.95E+6 hours.No.of failures 47. No.of demands not known. Failure mode include actuator failure, but not loss of power. Data based on experience with isolation valves.

VMTYF valve motor operated butterfly diameter between 6 and 12 inches

Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 4.7E-7/hr  95%: 9.1E-7/hr  5%: 2.5E-7/hr  ERROR FACTOR: 1.8  REPAIR TIME: 5 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.165.Cum.operating experience:12.95E+6 hours.No.of failures 6. Data based on experience with isolating valves with either electric or pneumatic operator.

VMFCT valve motor operated control valve

Component boundary: valve,motor,protection,controls,relays,logic and automation  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 2.5E-2/d  95%: 1.6E-1/d  REPAIR TIME: 4 hours
Source: Swedish Rel.data book, tbl.20  Ultimate source: plant operating experience(7 BWR plants), ATV reports
Comment: Total pop.69.No.of demands per operational time 2012.No.of failures 22. a=0.0971; b=3.75 Critical failures reported at 5 plants.
VMGAF valve motor operated gate diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean: 4.1E-6/hr 95%: 4.8E-6/hr 5%: 3.6E-6/hr ERROR FACTOR: 1.2
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.356. Cum. operating time 29.1E+6 hours. 120 failures. "All modes incl: 1) fail to operate, 2) external, 3) internal leak, 4) faulty indicator. 5) unspecified. 1), 2) and 5) dominant, 3) significantly lower.
REPAIR TIME: 15 hours

VMGCF valve motor operated gate diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY mean: 2.2E-6/hr 95%: 2.7E-6/hr 5%: 1.6E-6/hr ERROR FACTOR: 1.2
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.356. Cum. operating time 29.1E+6 hours. 63 failures. Number of demands in operational time is not known. "Fail to operate" incl. actuator failure, but not power supply to actuator.
REPAIR TIME: 21 hours

VMGYF valve motor operated gate diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean: 1.2E-6/hr 95%: 1.6E-6/hr 5%: 9.1E-7/hr
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.356. Cum. operating time 29.1E+6 hours. 35 failures.
ERROR FACTOR: 1.3
REPAIR TIME: 2 hours

VM1DW valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY median: 1.0E-4/d 95%: 3.0E-4/d 5%: 3.0E-5/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear experience (incl. test & research reactors)
Comment: This failure mode is given per demand and time related since phenomena is time related, but may be detected only upon a demand

VMASB valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leakage (catastrophic)
FAILURE RATE OR PROBABILITY mean: 1.0E-7/hr max: 7.0E-7/hr min: 1.0E-10/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment: Catastrophic leakage or "rupture" is assigned by engineering judgement. Catastrophic leakage assumes the valve to be in a closed state, then the valve fails
VMABI  valve motor operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leakage (catastrophic)
FAILURE RATE OR PROBABILITY  mean : 5.0E-7/hr  ERROR FACTOR: 100
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Catastrophic leakage or "rupture" assigned by engineering judgement. It assumes the valve to be in a closed state, then the valve fails.

VMACG  valve motor operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY  mean : 1.7E-5/hr  ERROR FACTOR: 3
Source: German Risk Study (pg.F3-74)  Ultimate source: generic data and operating experience
Comment: The same value is used in FTs for fail to open or close mode. For the standby operating mode, assuming monthly test interval failure per demand is 5.4E-3.

VMACJ  valve motor operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY  mean : 3.0E-3/d  ERROR FACTOR: 10
Source: NUREG 4550, Vol.1, tbl VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: Values used is from Station Blachout Study (NUREG/CR-3226). Two types of failures are included: valve hardware faults (5.0E-4) and command circuit faults (2.5E-4)

VMACW  valve motor operated general
Component boundary: detail n/a, include driver.  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  median: 1.0E-3/d  95%: 3.0E-3/d  5%: 3.0E-4/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Demand probabilities are based on presence of proper input signal. Failure to operate include changing state from closed to open or from open to closed position.

VMADB  valve motor operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: failure to remain open
FAILURE RATE OR PROBABILITY  mean : 2.0E-7/hr  max: 1.0E-6/hr  min: 8.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment:
VMADH valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean: 7.3E-8/hr 95%: 1.6E-7/hr 5%: 9.1E-9/hr
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 9.3E-8/hr. Operating experience 1.6E+6 hours of operation, no failures.

VMADI valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: fail to remain open
FAILURE RATE OR PROBABILITY mean: 1.0E-7/hr ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

VMADO valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean: 1.2E-7/hr 95%: 3.0E-7/hr 5%: 5.8E-9/hr
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: WASH 1400, MOV fail to remain open. 5%≈20%; 95%≈80%. Per demand rate converted to hrly rate assuming 1 demand in 45 days. Operating experience: 1.89E+6 hours of operation, no failures.

VMADW valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY median: 3.0E-7/hr 95%: 1.0E-6/hr 5%: 1.0E-6/hr ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: ultimate data source not known(sources presents plug per demand)
Comment: Failure to remain open refers to reduction of flow to unusable level due to foreign particles or gate failure. Not included in value inadvertant or false signal driving valve closed.

VMADZ valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean: 5.3E-8/hr
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant specific experience
Comment: Also applicable to manual valves. Prior: WASH 1400, fail to remain open, plugged. 1 demand in 45 days used to convert to hourly rate. Operating experience: 1.11E+7 hours of operation, no failures.
VMADZ valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: transfer open /excessive leakage through valve
FAILURE RATE OR PROBABILITY mean : 3.1E-8/hr
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant operating experience
Comment: Priors:NUREG 1363 MOV+remote(PWR),external leakage (mean)and WASH 1400, MOV, external elakage/rupture (distribution).
Operating experience:6.95E+5 hours of operation, no failures.

VMAEB valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean : 1.0E-5/hr max: 5.0E-5/hr min: 2.0E-7/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment:

VMAEH valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY mean : 9.2E-4/d 95%: 1.6E-3/d 5%: 2.8E-4/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.3E-3/d. Operating experience 5315 demands, 3 failures.

VMAEI valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean : 3.0E-3/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

VMAOB valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean : 1.0E-5/hr max: 5.0E-5/hr min: 2.0E-7/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment:
VMAOH valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY mean: 2.9E-3/d 95%: 3.8E-3/d 5%: 1.7E-3/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.3E-3/d. Operating experience 5315 demands, 15 failures.

VMAOI valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean: 3.0E-3/d ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment:

VMATU valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: internal leakage
FAILURE RATE OR PROBABILITY mean: 2.0E-6/hr
Source: Sizewell B (PWR/RX312 pg.7) Ultimate source: assessed from nuclear experience and generic data
Comment: Assessment based on W data item nad WASH 1400. Generic failure mode is based on FM assigned to W-1400, because it is not clearly defined here. Assessed failure rate is said to be very pessimistic.

VMATW valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: rupture
FAILURE RATE OR PROBABILITY median: 1.0E-8/hr 95%: 1.0E-7/hr 5%: 1.0E-9/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from US nuclear experience
Comment: Failure mode comparable with external leak.

VMAYJ valve motor operated general
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: fails from plugging
FAILURE RATE OR PROBABILITY mean: 4.0E-5/d ERROR FACTOR: 3
Source: NUREG 4550, Vol.1.tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: Value based on NRC LER data summary (1.0E-7/hr) assuming monthly system test (720 hrs).
VMVDS valve motor operated general
Component boundary: detail n/a  Operating mode: normally closed  Operating environment: normal
Generic failure mode: fail to remain in position*  Original failure mode: failed closed
FAILURE RATE OR PROBABILITY  mean : 1.5E-6/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

VMWDS valve motor operated general
Component boundary: detail n/a  Operating mode: normally open  Operating environment: normal
Generic failure mode: fail to remain in position*  Original failure mode: failed open
FAILURE RATE OR PROBABILITY  mean : 1.6E-6/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

VHXDS valve motor operated general
Component boundary: detail n/a  Operating mode: normally open  Operating environment: normal
Generic failure mode: fail to remain in position*  Original failure mode: failed closed
FAILURE RATE OR PROBABILITY  mean : 1.5E-7/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

VMYDS valve motor operated general
Component boundary: detail n/a  Operating mode: normally closed  Operating environment: normal
Generic failure mode: fail to remain in position*  Original failure mode: failed open
FAILURE RATE OR PROBABILITY  mean : 1.6E-7/hr
Source: Shoreham PRA,GE data(tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

VMQCE valve motor operated general (BWR application)
Component boundary: detail n/a(generally exclude driver)  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY  rec : 8.0E-3/cy
Comment: Reference EGG-EA 5B16 1982.
VMQOE valve motor operated general (BWR application)
Component boundary: detail n/a (generally exclude operator) Operating mode: all Operating environment: normal
Generic failure mode: plug Original failure mode: plugged
FAILURE RATE OR PROBABILITY rec : 6.0E-8/hr
Comment: Reference EGHG-EA-5B16 1982.

VMQYE valve motor operated general (BWR application)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leakage
FAILURE RATE OR PROBABILITY rec : 8.0E-8/hr
Comment: Reference EGG-EA-5B16 1982.

VMPCE valve motor operated general (PWR application)
Component boundary: detail n/a (generally excludes operator) Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: fail to operate
FAILURE RATE OR PROBABILITY rec : 4.0E-3/cy
Comment: Reference EGG-EA-5B16 1982.

VMPQE valve motor operated general (PWR application)
Component boundary: detail n/a (generally excludes driver) Operating mode: all Operating environment: normal
Generic failure mode: plug Original failure mode: plugged
FAILURE RATE OR PROBABILITY rec : 6.0E-8/hr
Source: IEEE 500 (1984) pg.1022 Ultimate source: expert judgement aggregation (delphi procedure) and experience
Comment: Reference EGG-EA-5B16

VMPYE valve motor operated general (PWR application)
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leakage
FAILURE RATE OR PROBABILITY rec : 1.0E-7/hr
Source: IEEE 500 (1984) pg.1022 Ultimate source: expert judgement aggregation (delphi procedure) and experience
Comment: Reference EGG-EA-5B169
VMLBF valve motor operated globe diameter between 2 and 6 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: internal leak  Original failure mode: internal leak  
FAILURE RATE OR PROBABILITY mean: 2.3E-6/hr  95%: 3.1E-6/hr  5%: 1.8E-6/hr  ERROR FACTOR: 1.3  REPAIR TIME: 4 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop. 220. Cum. operating time 1.4E+6 hours. 33 failures. Data based on experience with isolating valves.

VMLCF valve motor operated globe diameter between 2 and 6 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: fail to operate  
FAILURE RATE OR PROBABILITY mean: 1.3E-6/hr  95%: 1.9E-6/hr  5%: 9.0E-7/hr  ERROR FACTOR: 1.1  REPAIR TIME: 5 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop. 220. Cum. operating time 1.4E+6 hours. 18 failures. No. of demands in operational time is not known. Data based on experience with isolating valves. FM incl. actuator failure, but not power supply.

VMLYF valve motor operated globe diameter between 2 and 6 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: leakage/external leak  Original failure mode: external leak  
FAILURE RATE OR PROBABILITY mean: 6.3E-6/hr  95%: 7.5E-6/hr  5%: 5.3E-6/hr  ERROR FACTOR: 1.2  REPAIR TIME: 6 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop. 220. Cum. operating time 1.4E+6 hours. 89 failures. Data based on experience with isolating valves with either electric or pneumatic operator.

VMLAF valve motor operated globe diameter between 2 and 6 inches  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: all modes  Original failure mode: all modes  
FAILURE RATE OR PROBABILITY mean: 1.3E-5/hr  95%: 1.5E-5/hr  5%: 1.1E-5/hr  ERROR FACTOR: 1.1  REPAIR TIME: 9 hours  
Source: HWR data  Ultimate source: HWR operating experience  
Comment: Pop. 220. Cum. operating time 1.4E+6 hours. 187 failures. "All modes" incl.: 1) fail to operate, 2) external, 3) internal leak, 4) faulty indic., 5) spurious operation, 6) unspecified. 1), 2), 3) and 6) dominate, 5) minor.

VMOCY valve motor operated isolation valve pipe dimension 100 < DN < 200 mm  
Component boundary: valve, motor, protection, control, switch, fuse, indications  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: fail to change position  
FAILURE RATE OR PROBABILITY mean: 1.7E-3/d  
Source: Swedish Rel. data book, tbl. 12  Ultimate source: plant operating experience (Ringhals 2 PWR), ATV reports  
Comment: Total pop. 12. Number of demands per operational time 600. Number of failures 1. FAILMODE regarded open/close operation as one demand.
VMOCT  valve motor operated isolation valve pipe dimension 100< DN < 200 mm
Component boundary: valve,motor,protection,controls,switch,fuse,indications Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 6.3E-3/d 95%: 3.7E-2/d REPAIR TIME: 4 hours
Source: Swedish Rel.data book, tbl.12 Ultimate source: plant operating experience(7 BWR plants), ATV reports, LERs
Comment: Total pop.180.Number of demands per operational time 6181.Number of failures:30. a=0.114; b=18 Critical failures occured at 6 plants.

VMNCY valve motor operated isolation valve pipe dimension > 200 mm
Component boundary: valve,motor,protection,controls,switch,fuse,indications Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 3.3E-3/d REPAIR TIME: 8 hours
Source: Swedish Rel.data book, tbl.13 Ultimate source: plant operating experience(Ringhals 2 PWR) ATV reports
Comment: Total pop. 23.Number of demands per operational time 1486.Number of failures 5.

VMKCT valve motor operated isolation valve pipe dimension > 200mm
Component boundary: valve,motor,protection,controls,switch,fuse,indications Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 7.2E-3/d 95%: 4.2E-2/d REPAIR TIME: 5 hours
Source: Swedish Rel.data book, tbl.13 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop.95.Number of demands per operational time 3059.Number of failures 22. a= 0.11; b=15.2 Critical failures occured at 4 plants.

VMKCY valve motor operated isolation valve pipe dimension<=100 mm
Component boundary: valve,motor,protection,controls,switch,fuse,indications Operating mode: alt Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 7.9E-3/d 95%: 3.6E-2/d REPAIR TIME: 4 hours
Source: Swedish Rel.data book, tbl.11 Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop.71.Number of demands per operational time 2512.Number of failures observed: 18. a=0.307; b=38.5. Critical failures occured at 6 plants.

VMKCY valve motor operated isolation valve pipe dimension<=100mm
Component boundary: valve,motor,protection,controls,switch,fuse,indications Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 5.3E-3/d REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.11 Ultimate source: plant operating experience (Ringhals 2 PWR)
Comment: Total pop.22.Number of demands per operational time 983.Number of failures:5.
VMRCG valve motor operated regulating
Component boundary: valve with operator  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to close (in terms of regulating)
FAILURE RATE OR PROBABILITY  mean: 1.0E-5/hr  ERROR FACTOR: 7
Source: German Risk Study (pg.F3-79)  Ultimate source: generic data
Comment: Failure rate is combination of generic data sources

VMACU valve motor operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  mean: 2.0E-6/hr
Source: Sizewell B (PWR/RX312 pg.6)  Ultimate source: assessed from nuclear experience and generic sources
Comment: Assessment based on W data item and WASH 1400 data. If valves are tested monthly, given failure rate gives the peak probability of 1.4E-3/d, what is in agreement with WASH 1400.

VSROT valve pilot valve operated safety valve pipe dimension 125,150,300 mm
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean: 7.8E+4/d  95%: 1.4E+3/d  REPAIR TIME: 9 hours
Source: Swedish Rel.data book, tbl.22  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop.126. No. of demands 1281. No of failures 1. a = 0.0167; b = 21.4. Pilot valve see “vwmot”. Safety valve + pilot valve= pressure relief system. Critical failure on one plant only.

VSOCG valve pilot valve operated safety valve (pressurizer or main steam line) with one pilot valve
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY  median: 7.0E-3/d  ERROR FACTOR: 4
Source: German Risk Study (tb.F3.7-1)  Ultimate source: operating experience
Comment: Operating experience: 20 test and 80 operational demands, no failures. Not applicable to water relief safety valves.

VSTEG valve pilot valve operated safety valve (pressurizer or main steam line) with two or three pilot valves
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY  median: 7.0E-3/d  ERROR FACTOR: 4
Source: German Risk Study (tb.F3.7-1)  Ultimate source: operating experience
Comment: Operating experience: 20 test and 80 operational demands, no failures. Failure rate is not influenced by number of pilot valves. Not applicable to water relief safety valves.
VSTOG  valve pilot valve operated safety valve (pressurizer or main steam line) with two or three pilot valves  
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal  
Generic failure mode: fail to open  Original failure mode: fail to open  
FAILURE RATE OR PROBABILITY median: 4.0E-3/d  ERROR FACTOR: 6  
Source: German Risk Study (tb.F3.7-1)  Ultimate source: operating experience  
Comment: Operating experience: 20 test and 80 operational demands, no failures reported. It is assumed that having more than one pilot valve lower actual valve opening failure rate. N/a to water relief.  

VPTDH  valve piston operated butterfly used in HVAC  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to remain in position  Original failure mode: transfer closed  
FAILURE RATE OR PROBABILITY mean: 1.7E-7/hr  95%: 4.3E-7/hr  5%: 1.4E-8/hr  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 2.7E-7/hr. Operating experience 9.3E+5 hours of operation, no failures.  

VPTEN  valve piston operated butterfly used in HVAC  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to close  Original failure mode: fail to close on demand  
FAILURE RATE OR PROBABILITY mean: 1.2E-3/d  95%: 1.4E-3/d  5%: 8.3E-4/d  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 1.5E-3/d. Operating experience 24713 demands, 30 failures.  

VPTOH  valve piston operated butterfly used in HVAC  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to open  Original failure mode: fail to open on demand  
FAILURE RATE OR PROBABILITY mean: 1.9E-3/d  95%: 2.2E-3/d  5%: 1.4E-3/d  
Source: Old PWR  Ultimate source: generic data updated with plant operating experience  
Comment: Generic mean 1.5E-3/d. Operating experience 24713 demands, 49 failures.  

VPACO  valve piston operated general  
Component boundary: detail n/a  Operating mode: all  Operating environment: normal  
Generic failure mode: fail to change position  Original failure mode: failure to operate  
FAILURE RATE OR PROBABILITY mean: 3.5E-3/d  95%: 4.9E-3/d  5%: 1.6E-3/d  
Source: Oconee WPP PRA (tbI.b-1.)  Ultimate source: generic data updated with plant specific operating experience  
Comment: Prior: NUREG 1363, PWR air-op valves, failure on demand, w/o command. Operating experience: 2564 demands, 10 failures.
VPADO valve piston operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY mean : 1.9E-7/hr  95%: 5.5E-7/hr  5%: 6.8E-9/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: WASH 1400, air-op, failure to remain open. 5% = 20%; 95% = 80% Per demand rate converted to hourly rate assuming 1 dem. in 45 days. Operating experience: 2.74E+5 hours of operation, no failures.

VAGOT valve pneumatic operated isolation valve hydraulic scram system valve, pipe dimension <100 mm
Component boundary: valve, operator, control equipment, relays, logic and automation  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean : 1.4E-4/d  95%: 3.3E-4/d  REPAIR TIME: 4 hours
Source: Swedish Rel. data book, tbl.17  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop. 278. No. of demands per operational time 27816. No. of failures 4. a=0.0203; b=141. Critical failures occurred at one plant.

VAHCT valve pneumatic operated isolation valve pipe dimension <=100 mm
Component boundary: valve, operator, control equipment, relays, logic and automation  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 5.9E-3/d  95%: 3.4E-2/d  REPAIR TIME: 6 hours
Source: Swedish Rel. data book, tbl.16  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop. 86. No. of demands per operational time 2366. 14 failures a=0.129; b=21.7. Critical failures occurred at 4 plants.

VAHCY valve pneumatic operated isolation valve pipe dimension <=100 mm
Component boundary: valve, operator, control equipment, relays, logic and automation  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 6.5E-3/d  REPAIR TIME: 5 hours
Source: Swedish Rel. data book, tbl.16  Ultimate source: plant operating experience (Ringhals 2 PWR)
Comment: Total pop. 33. No. of demands per operational time 1236, no. of failures 8.

VRPOU valve power operated relief PORV
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean : 2.6E-6/hr
Source: Sizewell B (PWR/RX312 pg.5)  Ultimate source: assessed from nuclear experience and data
Comment: The same failure rate applicable for safety valves. Assessment based on W data, WASH 1400 adn SRS data item (7.0E-3/d). For yearly testing standby failure rate (2.6E-6/hr) gives peak rate 2.3E-2/d (pessimistic).
VRPEH  valve power operated relief PORV
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY  mean : 3.3E-2/d  95%: 6.7E-2/d  5%: 1.0E-2/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.5E-2/d. Operating experience 8 demands, 1 failure.

VRPEO  valve power operated relief PORV
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close
FAILURE RATE OR PROBABILITY  mean : 1.1E-2/d  95%: 3.0E-2/d  5%: 6.9E-4/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363. Failure to reclose after water or steam relief has the same distribution, based on EPRI valve test program.

VRPOH  valve power operated relief PORV
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY  mean : 4.2E-3/d  95%: 8.6E-3/d  5%: 1.0E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 4.3E-3/d. Operating experience 8 demands, no failures.

VRPOO  valve power operated relief PORV
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 4.9E-3/d  95%: 1.1E-2/d  5%: 2.1E-4/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience

VRPEJ  valve power operated relief valve PORV
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fails to reclose
FAILURE RATE OR PROBABILITY  mean : 3.0E-2/d  ERROR FACTOR: 10
Source: NUREG 4550, Vol.1,tbl.VII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: This value is also applicable to Safety Relief Valves. ASEP used generic value from IREP procedure guide, but it also falls into the range indicated by LERs.
VRPEU valve power operated relief valve POVR
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY  mean : 5.0E-6/d
Source: Sizewell B (PWR/RX312 pg.5)  Ultimate source: assessed from nuclear experience and data
Comment: Assessment based on W data item and SRS data item applicable to PORV's(4.0E-2/d) If PORVs are tested yearly, stdby failrate(5E-6/h) gives peak probability of 4.4E-2/d, what is consistent with SRS

VWCCA valve remote operated PORV block valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fails to transfer on demand
FAILURE RATE OR PROBABILITY  median: 3.6E-2/d  ERROR FACTOR: 2.4
Source: NUREG 4550/Vol.3,tbl.IV.8-1  Ultimate source: Surry NPP operating experience
Comment:

VCA8B valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leakage minor
FAILURE RATE OR PROBABILITY  mean : 3.0E-6/hr  max: 2.0E-5/hr  min: 6.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment:

VCA8B valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leakage catastrophic
FAILURE RATE OR PROBABILITY  mean : 1.0E-7/hr  max: 7.0E-7/hr  min: 1.E-10/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment: Valve initially closed, then failed

VCA8G valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leakage
FAILURE RATE OR PROBABILITY  mean : 3.9E-5/hr  ERROR FACTOR: 10
Source: German Risk Study (pg.P3-78)  Ultimate source: generic data
Comment: Failure rate is combination of several data sources. Operating experience revealed two values, 2.6E-5/hr and 4.2E-6/hr with 2 and 5 recorded events, respectively
VCA81 valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leakage (catastrophic)
FAILURE RATE OR PROBABILITY  mean : 5.0E-7/hr  ERROR FACTOR: 100
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: This failure mode assume that valve initially closed than failed

VCA8W valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak (severe)
FAILURE RATE OR PROBABILITY  median : 3.0E-7/hr  95%: 1.0E-6/hr  5%: 1.0E-7/hr  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from industrial, military and other experience and data
Comment: Internal leak is failure mode comparable to fail to close.

VCA9I valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leakage (minor)
FAILURE RATE OR PROBABILITY  mean : 3.0E-5/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:

VCAAE valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY  rec : 2.1E-6/hr  high: 3.3E-4/hr  low: 8.0E-8/hr  REPAIR TIME: 1.8 hours
Comment: ref: Corps of Engineers R/M data base, NPRD-2, NERS 80-02, NUREG 2232 Given value is composite of different sources, constructions and sizes of check valves Per cycle val. 9.6E-5/cy. FM comment angle vlv.

VCADH valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 1.0E-8/hr  95%: 2.1E-8/hr  5%: 2.4E-9/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.0E-8/hr. Operating experience 2.2E+6 hours of operation, no failures.
VCAEB  valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY  mean : 2.0E-6/hr  max: 1.0E-5/hr  min: 6.0E-7/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment:

VCAEG  valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY  mean : 3.1E-6/hr  ERROR FACTOR: 3
Source: German Risk Study (pg.3-77)  Ultimate source: generic data
Comment: Failure rate used is combination of several generic data sources. Regarding operating experience, there was 1 recorded failure in
2.6E+6 hours, what is comparable to generic, so it was used.

VCAEH  valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY  mean : 2.8E-4/d  95%: 4.5E-4/d  5%: 1.4E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-4/d. Operating experience 14262 demands, 5 failures.

VCAEI  valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY  mean : 1.0E-3/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tbl.5.1-1)  Ultimate source: expert opinion
Comment: Hourly rate 3.0E-6(EF 10) based on one actuation per month

VCAEJ  valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fails to close (causing back leakage)
FAILURE RATE OR PROBABILITY  mean : 1.0E-3/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1,tbl.VII.1.1-2  Ultimate source: assessed from several nuclear data sources
Comment: Value used in from IREP Procedure Guide.
VCAES valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fails to prevent flow
FAILURE RATE OR PROBABILITY  mean : 1.6E-6/hr
Source: Shoreham PRA,GE data(tbl.A.2.1)  Ultimate source: evaluation of BWR operating experience
Comment:

VCAEZ valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to seat/excessive leakage
FAILURE RATE OR PROBABILITY  mean : 8.4E-7/d
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Preors: NUREG 1363 check valve(PWR), internal leakage (mean) and WASH 1400, check valves, reverse leakage (distrib).
Operating experience: 6.08E+5 hours of operation, no failures.

VCAOB valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 2.0E-7/hr  max: 1.0E-6/hr  min: 8.0E-8/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment:

VCAOH valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY  mean : 1.8E-4/d  95%: 2.8E-4/d  5%: 6.9E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-4/d. Operating experience 14262 demands, 2 failures.

VCAOI valve self operated check
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 1.0E-4/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Hourly rate is 3.0E-7 (EF 10), based on one actuation per month
VCAOJ valve self operated check
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fails to open
FAILURE RATE OR PROBABILITY mean: 1.0E-4/d ERROR FACTOR: 3
Source: NUREG 4550, Vol.1,tbl.VIII.1-2 Ultimate source: assessed from several nuclear data sources
Comment: Generic value developed in Station Blackout Study was used.

VCAOS valve self operated check
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fails to permit flow
FAILURE RATE OR PROBABILITY mean: 1.5E-7/hr
Source: Shoreham PRA,GE data(tb.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment:

VCAOW valve self operated check
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY median: 1.0E-4/d 95%: 3.0E-4/d 5%: 3.0E-5/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear, industrial and military experience and data
Comment:

VCAOZ valve self operated check
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open on demand
FAILURE RATE OR PROBABILITY mean: 4.3E-5/d
Source: ZION NPP PSS (tbl.1.5.1-5) Ultimate source: generic data updated with plant operating experience
Comment: Prior:NUREG 1363 check valves(PWR), fail to open (mean) and WASH 1400 check valves, fail to open (distrib.). Operating experience: 6,968 demands, no failures.

VCATW valve self operated check
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: rupture Original failure mode: rupture
FAILURE RATE OR PROBABILITY median: 1.0E-8/hr 95%: 1.0E-7/hr 5%: 1.0E-9/hr ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from nuclear and industrial experience and data
Comment: Rupture is failure mode comparable to external leak.
VCEOG valve self operated check ECCS & RHR systems
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY mean : 7.1E-7/hr ERROR FACTOR: 4
Source: German Risk Study (pg.P3-76) Ultimate source: operating experience
Comment: Operating experience: 1.5E+6 operating hours, no failures. For other check valves combination of generic data sources with failure rate of 2.1E-6/hr (EF 10) was used in FTs.

VCFOV valve self operated check ESF system valves
Component boundary: valve body and interiors Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean : 6.4E-5/d 95%: 1.7E-4/d 5%: 1.7E-5/d
Comment: Overall standy hourly failure rate 3.0E-8/hr.

VCF8V valve self operated check ESF systems valves
Component boundary: valve body and interiors Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: reverse leakage
FAILURE RATE OR PROBABILITY mean : 5.4E-7/hr 95%: 7.0E-7/hr 5%: 4.1E-7/hr
Comment: Overall rate. BWR 2 times higher than PWR.

VCFYV valve self operated check ESF systems valves
Component boundary: valve body and interiors Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: leak externally
FAILURE RATE OR PROBABILITY mean : 4.9E-8/hr 95%: 1.0E-7/hr 5%: 1.9E-8/hr
Comment: Overall rate. BWR higher than PWR.

VCAEU valve self operated check applicable to all check valves in safeguard systems and main feed
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean : 2.0E-6/hr
Source: Sizewell B (PWR/RX312 pg.4) Ultimate source: assessed from nuclear experience and data
Comment: Assessment based on W data items, literature data, and SRS data item (2.0E-4/d). For monthly tested valves stdby prob. of 2.0E-6/hr gives peak failure prob.of 1.4E-3/d what is pessimistic.
VCAOU valve self operated check applicable to all check valves in safeguards system and main feed
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean : 1.0E-7/hr
Source: Sizewell B (PWR/RX312 pd.4) Ultimate source: assessed from nuclear experience and data
Comment: Assessment based on 2 W data item, WASH 1400, and SRS data item (PWR) (5.0E-5/d). For monthly tested valves stdby fail rate of 1.0E-7/hr gives peak failure rate of 7.2E-5/d. Consistent with other sources

VCS8F valve self operated check diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 5.3E-7/hr 95%: 7.3E-7/hr 5%: 3.9E-7/hr ERROR FACTOR: 1.3 REPAIR TIME: 9 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.662. Cum.operating time 51E+6 hours. No.of failures 27.

VCL8F valve self operated check diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 6.2E-7/hr 95%: 9.5E-7/hr 5%: 4.1E-7/hr ERROR FACTOR: 1.5 REPAIR TIME: 12 hours
Source: HWR data Ultimate source: HWR operating experience

VCLAF valve self operated check diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 2.2E-6/hr 95%: 2.8E-6/hr 5%: 1.8E-6/hr ERROR FACTOR: 1.2 REPAIR TIME: 12 hours
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.343. Cum.operating time 24.4E+6 hours. No.of failures 54. "All modes" include: 1) fail to open, 2) fail to close, 3) external, 4) internal leak, 5) unspecified. 1) completely negligible (no failures occurring)

VCLEF valve self operated check diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close
FAILURE RATE OR PROBABILITY mean : 1.2E-7/hr 95%: 3.2E-7/hr 5%: 5.7E-8/hr ERROR FACTOR: 2.1 REPAIR TIME: 19 hours
Source: HWR data Ultimate source: HWRW operating experience
Comment: Pop.343. Cum.operating time 24.4E+6 hours. No.of failures 3. No.of demands in cumulative component operating time is not known.
VCLYF valve self operated check diameter between 12 and 24 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 9.8E-7/hr 95%: 1.4E-6/hr 5%: 7.1E-7/hr ERROR FACTOR: 1.4
Source: HWR data Ultimate source: HWR operating experience

VCSAF valve self operated check diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: all modes Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.3E-6/hr 95%: 1.6E-6/hr 5%: 1.0E-6/hr ERROR FACTOR: 1.2
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.662. Cum.operating time 51E+6 hours. 67 failures. "All modes" include:1) fail to open, 2) fail to close, 3) external leak, 4) internal leak, 5) unspecified. 1) is negligible (no failures recorded).

VCSEF valve self operated check diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close
FAILURE RATE OR PROBABILITY mean : 1.1E-7/hr 95%: 2.2E-7/hr 5%: 6.8E-8/hr ERROR FACTOR: 1.8
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.662. Cum.operating time 51E+6 hours. 6 failures. No.of demands in cumulative operating time is not known.

VCSOF valve self operated check diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY mean : 1.9E-8/hr 95%: 9.2E-8/hr 5%: 6.8E-9/hr ERROR FACTOR: 2.8
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.662. Cum.operating time 51E+6 hours. 1 failure. No.of demands in cumulative operational time not known.

VCSYF valve self operated check diameter between 2 and 6 inches
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: leakage/external leak Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 2.1E-7/hr 95%: 3.5E-7/hr 5%: 1.3E-7/hr ERROR FACTOR: 1.6
Source: HWR data Ultimate source: HWR operating experience
Comment: Pop.662. Cum.operating time 51E+6 hours. No.of failures 11.
VCTBF  valve self operated check diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean : 4.5E-7/hr  95%: 7.1E-7/hr  5%: 3.0E-7/hr  ERROR FACTOR: 1.5  REPAIR TIME: 13 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.390. Cumulative component operating time 29E+6 hours. No.of failures 13.

VCTAF  valve self operated check diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 1.8E-6/hr  95%: 2.3E-6/hr  5%: 1.5E-6/hr  ERROR FACTOR: 1.2  REPAIR TIME: 12 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.390. Cumulative operating time 29E+6 hours. No.of failures 53. "All modes" include: 1) fail to open, 2) fail to close, 3) external leak, 4) internal leak, 5) unspecified, 1) completely negligible (no failure).

VCTEF  valve self operated check diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY mean : 1.4E-7/hr  95%: 3.2E-7/hr  5%: 6.8E-8/hr  ERROR FACTOR: 2  REPAIR TIME: 6 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.390. Cumulative component operating time 29E+6 hours. No.of failures 4. Number of demands per operational time is not known.

VCTYF  valve self operated check diameter between 6 and 12 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 7.2E-7/hr  95%: 1.2E-6/hr  5%: 5.9E-7/hr  ERROR FACTOR: 1.4  REPAIR TIME: 12 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.390. Cumulative component operational time 29E+6 hours. No.of failures 24.

VCHAF  valve self operated check diameter larger than 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 3.6E-6/hr  95%: 6.2E-6/hr  5%: 2.1E-6/hr  ERROR FACTOR: 1.6  REPAIR TIME: 10 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.48. Cumulative component operating time 2.52E+6 hours. 9 failures. "all modes" include 1) external leak, 2) unspecified.
valve self operated check diameter larger than 24 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean: 2.0E-6/hr  95%: 4.2E-6/hr  5%: 1.0E-6/hr  ERROR FACTOR: 1.9
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.48. Cumulative component operating time 2.52E+6 hours. 5 failures.

valve self operated check diameter less than 2 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: internal leak  Original failure mode: internal leak
FAILURE RATE OR PROBABILITY mean: 1.3E-7/hr  95%: 1.8E-7/hr  5%: 8.0E-8/hr  ERROR FACTOR: 1.4
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1907.Cum.operating time 1.4E+8 hours. No.of failures 17.

valve self operated check diameter less than 2 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close
FAILURE RATE OR PROBABILITY mean: 3.4E-8/hr  95%: 6.8E-8/hr  5%: 1.1E-8/hr  ERROR FACTOR: 2
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1907.Cum.operating time 1.4E+8 hours. No.of failures 4. No.of demands not known.

valve self operated check diameter less than 2 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open
FAILURE RATE OR PROBABILITY mean: 6.8E-9/hr  95%: 3.4E-8/hr  5%: 2.3E-9/hr  ERROR FACTOR: 3.0
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1907.Cum.operating time 1.4E+8 hours. No.of failure 1. No.of demands not known.
VCBYF  valve self operated check diameter less than 2 inches
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: external leak
FAILURE RATE OR PROBABILITY mean : 4.6E-8/hr  95%: 8.0E-8/hr  5%: 2.3E-8/hr  ERROR FACTOR: 1.8  REPAIR TIME: 4 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Pop.1907. Cum.operating time 1.4E+8 hours. No.of failures 6.

VCN1H  valve self operated check main steam check valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY mean : 2.4E-4/d  95%: 4.7E-4/d  5%: 5.2E-5/d
Source: Old PWR Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.7E-4/d. Operating experience 378 demands, no failures.

VCJET  valve self operated check pipe dimension > 100mm
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean : 3.4E-3/d  95%: 1.9E-2/d  REPAIR TIME: 9 hours
Source: Swedish Rel.data book, tbl.19  Ultimate source: plant operating experience(7 BWR plants), ATV reports, LERs
Comment: Total pop.168. No.of demands per operational time 3211. No.of failures 11. \(a=0.0568; b=16.5\) Critical failures reported at 5 plants.

VCSC1T  valve self operated check pipe dimension 500mm, 600 mm (main steam system)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean : 3.2E-3/d  95%: 1.9E-2/d
Source: Swedish Rel.data book, tbl.15  Ultimate source: plant operating experience(6 BWR plants), ATV reports, LERs
Comment: Total pop.24. Number of demands per operational time 632. No. of failures 2. \(a=0.09; b=28.3\) Critical failures reported on one plant only.

VCIET  valve self operated check pipe dimension <=100 mm
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean : 5.5E-4/d  REPAIR TIME: 12 hours
Source: Swedish Rel.data book, tbl.18  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop.417. No.of demands per operational time 3628. No of failures 2. \(a=0.0129; b=23.3\) Critical failures at one plant only.
No failure to open observed out of 3628 demands.
<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Component Boundary</th>
<th>Operating Mode</th>
<th>Operating Environment</th>
<th>Generic Failure Mode</th>
<th>Original Failure Mode</th>
<th>Failure Rate or Probability (mean)</th>
<th>Repair Time</th>
<th>Source</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCJOT</td>
<td>detail n/a</td>
<td>all</td>
<td>normal</td>
<td>fail to open</td>
<td>failure to open</td>
<td>6.3E-4/d</td>
<td>9 hours</td>
<td>Swedish Rel. data book, tbl.19</td>
<td>Total pop. 168; No of demands per operational time 3211. No of failures 1.a=0.071; 1.b=11.2 Critical failure at one plant only. Ringhals 2 PWR: no failure to open out of 1844 demands.</td>
</tr>
<tr>
<td>VCUDO</td>
<td>detail n/a</td>
<td>all</td>
<td>normal</td>
<td>fail to remain in position</td>
<td>transfer closed</td>
<td>1.8E-7/hr</td>
<td></td>
<td>Oconee NPP PRA (tbl.b-1.)</td>
<td>Prior: WASH 1400 failure of MOV to remain open. 5%=20%; 95%=80%. Per demand rate converted to hrly rate assuming 1 demand in 45 days of operation; 3.42E+5 hours of operation, no failures.</td>
</tr>
<tr>
<td>VCUEO</td>
<td>detail n/a</td>
<td>all</td>
<td>normal</td>
<td>fail to close</td>
<td>failure to close</td>
<td>1.6E-4/d</td>
<td></td>
<td>Oconee NPP PRA (tbl.b-1.)</td>
<td>Prior: NUREG 1363, check valve failure to close on demand. Operating experience: 321 demand, 1 failure. 95%/5% ratio is 10, indicating moderate degree of uncertainty.</td>
</tr>
<tr>
<td>VCJDI</td>
<td>detail n/a</td>
<td>all</td>
<td>normal</td>
<td>fail to open</td>
<td>failure to open</td>
<td>1.0E-4/d</td>
<td></td>
<td>IREP NUREG 2728 (tbl.5.1-1)</td>
<td></td>
</tr>
<tr>
<td>VCJDO</td>
<td>detail n/a</td>
<td>all</td>
<td>normal</td>
<td>fail to open</td>
<td>failure to open</td>
<td>9.9E-5/d</td>
<td></td>
<td>Oconee NPP PRA (tbl.b-1.)</td>
<td>Prior: NUREG 1363 check valve failure to open on demand. Operating experience: 251 demand, no failures. 95%/5% ratio is 10, indicating moderate degree of uncertainty.</td>
</tr>
</tbody>
</table>
VCWDO  valve self operated check swing
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 2.0E-7/hr  95%:  6.0E-7/hr  5%:  6.9E-9/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: WASH 1400 failure of MOV to remain open. 5%=20%; 95%=80%. Per demand rate converted to hrly rate assuming 1 demand in 45 days. Operating experience: 1.48E+5 hours of operation, no failures.

VCWEO  valve self operated check swing
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close
FAILURE RATE OR PROBABILITY  mean : 9.8E-5/d  95%:  2.1E-4/d  5%:  2.0E-5/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, check valve failure to close on demand. Operating experience: 426 demands, no failures. 95%/5% ratio is 10 indicating moderate degree of uncertainty.

VCWOO  valve self operated check swing
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 9.8E-5/d  95%:  2.1E-4/d  5%:  2.0E-5/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, check valve failure to open on demand. Operating experience: 427 demands, no failures. 95%/5% ratio is 10 indicating moderate degree of uncertainty.

VCNES  valve self operated check testable check valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fails to prevent flow
FAILURE RATE OR PROBABILITY  mean : 2.2E-6/hr
Source: Shoreham PRA, GE data (tb.A.2-1)  Ultimate source: evaluation of BWR operating experience
Comment:

VCZDO  valve self operated check tilting disc check valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 1.9E-7/hr  95%:  5.7E-7/hr  5%:  6.8E-9/hr
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: WASH 1400, failure of MOV to remain open. 5%=20%; 95%=80%. Per demand rate converted to hrly rate assuming 1 demand in 45 days. Operating experience: 2.39E+5 hours of operation, no failures.
VCZEO  valve self operated check tilting disc check valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean: 1.3E-4/d 95%: 2.7E-4/d 5%: 3.0E-5/d
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, check valve failure to close on demand. Operating experience: 2719 demands, 1 failure.
95%/5% ratio is 10 indicating moderate degree of uncertainty.

VCZOO  valve self operated check tilting disc check valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean: 8.7E-5/d 95%: 1.7E-4/d 5%: 1.9E-5/d
Source: Oconee NPP PRA (tbl.b-1.) Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: NUREG 1363, check valve failure to open on demand Operating experience: 2707 demands, no failures.
95%/5% ratio is 10 indicating moderate degree of uncertainty.

VCNOS  valve self operated check valve testable check valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fails to permit flow
FAILURE RATE OR PROBABILITY mean: 2.2E-7/hr
Source: Shoreham PRA, GE data (tb.A.2-1) Ultimate source: evaluation of BWR operating experience
Comment:

VSCEB  valve self operated code safety valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close, given open
FAILURE RATE OR PROBABILITY mean: 2.0E-5/hr max: 2.0E-4/hr min: 8.0E-6/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment: Applies to PWR only

VSCEI  valve self operated code safety valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close, given open
FAILURE RATE OR PROBABILITY mean: 1.0E-2/d ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: applies to PWR only
VSCOB valve self operated code safety valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 6.0E-7/hr  max: 4.0E-5/hr  min: 3.0E-6/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment: applies to PWR only. Premature opening covered under initiating events.

VSCOI valve self operated code safety valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 1.0E-5/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Applies to PWR only. Premature opening is treated as an initiating event.

VWKCG valve self operated pilot valve
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY  median: 4.0E-3/d  ERROR FACTOR: 6
Source: German Risk Study (tb.F3.7-1)  Ultimate source: operating experience
Comment: Operating experience: 60 test and 80 operational demands no failures.

VSDEO valve self operated pressurizer safety valve short inlet piping
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close
FAILURE RATE OR PROBABILITY  mean : 4.8E-3/d  95%: 1.0E-2/d  5%: 1.1E-3/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: Median, failure to reclose (steam relief) Babcock & Wilcox Co. Distribution based on EPRI test.
Operating experience: 10 demands, no failure. ONLY STEAM RELIEF

VSDOO valve self operated pressurizer safety valve short inlet piping
Component boundary: detail n/a  Operating mode: standby  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 2.7E-4/d  95%: 8.0E-5/d  5%: 7.4E-6/d
Source: Oconee NPP PRA (tbl.b-1.)  Ultimate source: generic data updated with plant specific operating experience
Comment: Prior: Median of General Atomic data base (GCR) for primary relief valves, range factor 10.
Operating experience: 10 demands, no failures.
VSBE8  valve self operated primary safety valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close, given open
FAILURE RATE OR PROBABILITY  mean : 2.0E-5/hr  max: 2.0E-4/hr  min: 8.0E-6/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment: applies to BWR only

VSBEI  valve self operated primary safety valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close, given open
FAILURE RATE OR PROBABILITY  mean : 3.0E-2/d  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: applies to BWR only

VSBOB  valve self operated primary safety valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 2.0E-5/hr  max: 2.0E-4/hr  min: 8.0E-6/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment: applies to BWR only

VSBOI  valve self operated primary safety valves
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: failure to open
FAILURE RATE OR PROBABILITY  mean : 1.0E-5/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: applies to BWR only

VRADG  valve self operated relief
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to remain in position*  Original failure mode: spurious opening
FAILURE RATE OR PROBABILITY  mean : 3.6E-6/hr  ERROR FACTOR: 7
Source: German Risk Study (pg.F3-83)  Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources.
VRSDZ valve self operated relief/safety
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: premature opening or leakage
FAILURE RATE OR PROBABILITY mean: 1.6E-6/hr
Source: ZION NPP PSS (tbl.1.5.1-5)  Ultimate source: generic data updated with plant operating experience
Comment: Priors NUREG 1363 safety valves(PWR), premature opening (mean) and WASH 1400 relief valves, premature opening (distrib.). Operating experience: 6.19E+5 hours of operation, 2 failures.

VSMEH valve self operated safety main steam
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY mean: 2.6E-3/d  95%: 7.1E-3/d  5%: 8.8E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.9E-3/d. Operating experience 10 demands, no failures.

VSMOH valve self operated safety main steam
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY mean: 3.3E-4/d  95%: 1.1E-3/d  5%: 1.3E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 3.3E-4/d. Operating experience 10 demands, no failures.

VSAEU valve self operated safety relief valve
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean: 7.0E-7/hr
Source: Sizewell B (PWR/RX312 pg.5)  Ultimate source: assessed from nuclear experience and data
Comment: Assessment based on W data item and SRS data applicable to SRVs, (6.0E-3/d). If SRV are tested yearly standby fail rate of 7.0E-7/hr gives the peak probability of 6.1E-3/d, what is pessimistic.

VVAEJ valve self operated safety relief valve BWR General Electric
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fails to open
FAILURE RATE OR PROBABILITY mean: 1.0E-5/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1, tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: Value used is taken from IREP Procedures Guide.
VSPDV valve self operated safety valves PWR
Component boundary: valve body and internals, operating mechanism Operating mode: all Operating environment: normal
Generic failure mode: fail to remain in position Original failure mode: premature open
FAILURE RATE OR PROBABILITY mean: 3.4E-6/hr 95%: 5.4E-6/hr 5%: 2.0E-6/hr
Comment:

VSPOV valve self operated safety valves PWR
Component boundary: valve body and internals, operating mechanism Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY mean: 3.9E-3/d 95%: 7.4E-3/d 5%: 1.8E-3/d
Comment: Overall data. Standby hourly rate is 1.7E-6/hr. Demand rate is taking into account 5 years test interval, and operational demands in observed period (demand=1/2 of all forced scrams, PWR)

VVAEB valve self operated vacuum breaker
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean: 6.0E-8/hr max: 4.0E-7/hr min: 2.0E-8/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment: applies to BWR only

VVAEI valve self operated vacuum breaker
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to close Original failure mode: failure to close
FAILURE RATE OR PROBABILITY mean: 1.0E-5/d ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: applies only to BWR

VVADB valve self operated vacuum breaker
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean: 6.0E-8/hr max: 4.0E-7/hr min: 2.0E-8/hr
Source: NUREG 2815 (table C.1.) Ultimate source: expert opinion and IREP data
Comment: applies to BWR only
VVAOI valve self operated vacuum breaker
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to open Original failure mode: failure to open
FAILURE RATE OR PROBABILITY mean: 1.0E-5/d ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1) Ultimate source: expert opinion
Comment: applies only to BWR

VVACW valve self operated vacuum valve
Component boundary: detail n/a Operating mode: all Operating environment: normal
Generic failure mode: fail to change position Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY median: 3.0E-5/d 95%: 1.0E-4/d 5%: 1.0E-5/d ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1) Ultimate source: assessed from industrial and military experience ana data
Comment: Failure to operate include changing state from closed to open or from open to closed position.

VCUEG valve self operated (motor operated) check stop check
Component boundary: including operator Operating mode: standby Operating environment: normal
Generic failure mode: fail to close Original failure mode: fail to close
FAILURE RATE OR PROBABILITY mean: 7.4E-6/hr ERROR FACTOR: 4
Source: German Risk Study (pg.F3-78) Ultimate source: generic data and operating experience
Comment: In FTs this component is included for isolation of accumulators. Operating experience for electrical operator part of valve gives failure rate of 4.3E-6/hr.

VCUGG valve self operated (motor operated) check stop check
Component boundary: without operator (motor) Operating mode: standby Operating environment: normal
Generic failure mode: fail to open Original failure mode: fail to open
FAILURE RATE OR PROBABILITY median: 1.5E-6/hr ERROR FACTOR: 10
Source: German Risk Study (tb.F3,7-1) Ultimate source: generic data sources
Comment: In FTs this component is included for isolation of accumulators. Principal reference NPRDS annual report 1976.

VCUGS valve self operated (motor operated) stop check
Component boundary: detail n/a Operating mode: standby Operating environment: normal
Generic failure mode: internal leak Original failure mode: internal leakage
FAILURE RATE OR PROBABILITY median: 1.0E-5/hr ERROR FACTOR: 10
Source: German Risk Study (tb.F3,7-1) Ultimate source: generic data
Comment: It is assumed that stop check valve is somewhat better in terms of probability of internal leak than regular check valve. Failure rate is combination of several generic sources.
VSADG  valve self operated (pilot operated) safety valve
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious opening
FAILURE RATE OR PROBABILITY  median: 2.0E-6/hr  ERROR FACTOR: 7
Source: German Risk Study (tb.F3,7-1)  Ultimate source: generic data
Comment: Failure rate is combination of several generic data sources.

VSRDT  valve self operated (pilot operated) safety valve (pressure relief system) pipe dimensions 125,150,300 mm
Component boundary: Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: spurious opening
FAILURE RATE OR PROBABILITY mean: 1.3E-6/d  95%: 7.5E-6/d  REPAIR TIME: 9 hours
Source: Swedish Rel.data book, tbl.22  Ultimate source: plant operating experience (7 BWR plants)
Comment: Critical failures reported on 2 plants. Spurious opening include all detected leakages at power. Operatin experience data for this failure mode n/a.

VSRTE  valve self operated (pilot operated) safety valve (pressure relief system) pipe dimensions 125,150,300 mm
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: failure to reclose
FAILURE RATE OR PROBABILITY mean: 2.4E-3/d  95%: 7.2E-3/d  REPAIR TIME: 9 hours
Source: Swedish Rel.data book, tbl.22  Ultimate source: plant operating experience (BWR plants), ATV reports, LERs
Comment: Total pop.126. No.of demands 1281. No.of failures 2. Pilot valve see "vwkct”. a=0.0232; b=9.67
Critical failures reported on 2 plants.

VRRCG  valve self operated (pilot or power operated) pressurizer relief
Component boundary: detail n/a  Operating mode: closed  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY median: 4.0E-3/d  ERROR FACTOR: 6
Source: German Risk Study (tb.F3,7-1)  Ultimate source: operating experience
Comment: Generic data seems not to be applicable due to different types and failure modes.

VWMCT  valve self operated, motor operated (redundant closure) stop check pipe dimension 500mm, 600mm (main steam system valve)
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to change position
FAILURE RATE OR PROBABILITY mean: 2.5E-2/d  95%: 7.7E-2/d  REPAIR TIME: 4 hours
Source: Swedish Rel.data book, tbl.14  Ultimate source: plant operating experience (6 BWR plants), ATV reports, LERs
Comment: Total pop.24. No.of demands per operational time 632. No.of failures 16. Fail. mostly related to open/close oper. by motor. Press closing function 10 times more reliable. a=0.937; b=36.1. Crit f. at 5 pl
VDODH  valve solenoid operated  all systems, except HVAC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 8.7E-7/hr  95%: 2.0E-6/hr  5%: 1.0E-7/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.3E-6/hr. Operating experience 8.1E+5 hours of operation, no failures.

VDOEH  valve solenoid operated  all systems, except HVAC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY  mean : 1.7E-3/d  95%: 2.9E-3/d  5%: 5.5E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 2263 demands, 4 failures.

VDOWH  valve solenoid operated  all systems, except HVAC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY  mean : 1.0E-3/d  95%: 1.7E-3/d  5%: 2.4E-4/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 2263 demands, 2 failures.

VDHDH  valve solenoid operated  used in HVAC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: transfer closed
FAILURE RATE OR PROBABILITY  mean : 7.9E-7/hr  95%: 2.2E-6/hr  5%: 4.5E-8/hr
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 1.3E-6/hr. Operating experience 2.6E+5 hours of operation, no failures.

VDHEH  valve solenoid operated  used in HVAC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to close  Original failure mode: fail to close on demand
FAILURE RATE OR PROBABILITY  mean : 8.0E-4/d  95%: 1.7E-3/d  5%: 7.6E-5/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 538 demands, no failures.
VDHOH valve solenoid operated used in HVAC
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to open  Original failure mode: fail to open on demand
FAILURE RATE OR PROBABILITY mean : 7.4E-3/d  95%: 1.2E-2/d  5%: 3.7E-3/d
Source: Old PWR  Ultimate source: generic data updated with plant operating experience
Comment: Generic mean 2.4E-3/d. Operating experience 538 demands, 5 failures.

VDAAF valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: all modes  Original failure mode: all modes
FAILURE RATE OR PROBABILITY mean : 2.7E-7/hr  95%: 3.5E-7/hr  5%: 2.1E-7/hr  ERROR FACTOR: 1.3  REPAIR TIME: 5 hours
Source: HWR data  Ultimate source: HWR operating experience
Comment: Source: Pop.2635. Cum.operating time 145.2E+6 hours. 39 failures."All modes incl:1)passing,2)plugged,3)faulty operation,4)unspecified.Contrib of 4)is dominant, other about equal (6 times lower)

VDACB valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 2.0E-6/hr  max: 1.0E-5/hr  min: 8.0E-7/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert opinion and IREP data
Comment:

VDACG valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fail to open or to close
FAILURE RATE OR PROBABILITY mean : 3.7E-5/hr  ERROR FACTOR: 20
Source: German Risk Study (pg.P3-75)  Ultimate source: generic data
Comment: There is no specific operating experience data for this component and failure rate is combination of several generic data sources (6).

VDACI valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY mean : 1.0E-3/d  ERROR FACTOR: 3
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment:
VDACJ valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: fails to operate
FAILURE RATE OR PROBABILITY  mean : 1.0E-3/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1, tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: Same value as for air operated valve. Two types of failures included in the failure rate: valve hardware fault (1.0E-3) and command circuit faults (1.0E-4).

VDACW valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to operate
FAILURE RATE OR PROBABILITY  median: 1.0E-3/d  95%: 3.0E-3/d  5%: 3.0E-4/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: assessed from nuclear, industrial and military experience and data
Comment: Based on presence of proper input signal. Failure of a valve to operate includes changing state from closed to open or from open to closed position.

VDADW valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: fail to remain in position  Original failure mode: failure to remain open (plug)
FAILURE RATE OR PROBABILITY  median: 1.0E-4/d  95%: 3.0E-4/d  5%: 3.0E-5/d  ERROR FACTOR: 3
Source: WASH 1400 (table III 4-1)  Ultimate source: ultimate data source not known
Comment: Failure to remain open refers to reduction of flow to unusable level due to foreign material or gate failure. Not included in data is inadvertent or false signal driving valve closed.

VDATW valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: rupture  Original failure mode: rupture
FAILURE RATE OR PROBABILITY  median: 1.0E-8/hr  95%: 1.0E-7/hr  5%: 1.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400 (table III 4-1)  Ultimate source: ultimate data source not known
Comment:

VDAYJ valve solenoid operated general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: leakage/external leak  Original failure mode: fails from plugging
FAILURE RATE OR PROBABILITY  mean : 4.0E-5/d  ERROR FACTOR: 3
Source: NUREG 4550, Vol.1, tbl.VIII.1-2  Ultimate source: assessed from several nuclear data sources
Comment: The same value as for air operated valve. Value is based on NRC LER data summary (1.0E-7/hr) assuming one month (720 hrs) test interval.
VDNCT  valve solenoid operated general (normally activated)
Component boundary: detail n/a  Operating mode: normally activated  Operating environment: normal
Generic failure mode: fail to change position  Original failure mode: failure to function
FAILURE RATE OR PROBABILITY  mean : 7.1E-7/hr  95%: 3.7E-6/hr  REPAIR TIME: 3 hours
Source: Swedish Rel.data book, tbl.23  Ultimate source: plant operating experience (7 BWR plants), ATV reports, LERs
Comment: Total pop.513. Operating time 2260E+4 hours. No.of failures 16. Critical failures reported on 2 plants.
a=0.0487; b=88600

CWCGW  wire control circuit wire typical circuit, several joints
Component boundary: wire section with soldered and lug connection to comp.& term board  Operating mode: all  Operating environment: normal
Generic failure mode: short to ground  Original failure mode: short to ground
FAILURE RATE OR PROBABILITY  median: 3.0E-7/hr  95%: 3.0E-6/hr  5%: 3.0E-8/hr  ERROR FACTOR: 10
Source: WASH 1400  (table III 4-2)  Ultimate source: assessed from nuclear, industrial experience and expert opinion
Comment: Data do not permit a unique separation of failure modes in all cases; hence failure modes listed for wires and terminal boards are not necessary independent, and should not be combined.

CWCHW  wire control circuit wire typical circuit, several joints
Component boundary: wire section with soldered and lug connection to comp.& term board  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short to power
FAILURE RATE OR PROBABILITY  median: 1.0E-8/hr  95%: 1.0E-7/hr  5%: 1.0E-9/hr  ERROR FACTOR: 10
Source: WASH 1400  (table III 4-2)  Ultimate source: assessed from industrial experience and expert opinion
Comment: Data do not permit a unique separation of failure modes in all cases; hence failure modes listed for wires and terminal boards are not necessary independent, and should not be combined.

CWCIW  wire control circuit wire typical circuit, several joints
Component boundary: wire section with soldered and lug connection to comp.& term board  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open circuit
FAILURE RATE OR PROBABILITY  median: 3.0E-6/hr  95%: 1.0E-5/hr  5%: 1.0E-6/hr  ERROR FACTOR: 3
Source: WASH 1400  (table III 4-2)  Ultimate source: assessed from industrial, nuclear experience, expert opinion
Comment: Data do not permit a unique separation of failure modes in all cases; hence failure modes listed for wires and terminal boards are not necessary independent, and should not be combined.

CWAGB  wire general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short to ground  Original failure mode: short to ground
FAILURE RATE OR PROBABILITY  mean : 1.0E-6/hr  max: 5.0E-6/hr  min: 2.0E-8/hr
Source: NUREG 2815  (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:
CWAGI  wire general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short to ground  Original failure mode: short to ground
FAILURE RATE OR PROBABILITY  mean : 3.0E-7/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Given value is per circuit Given value is consistent with IEEE 500 data for 1000 ft circuit

CWAHB  wire general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short to power
FAILURE RATE OR PROBABILITY  mean : 3.0E-8/hr  max: 2.0E-7/hr  min: 6.0E-10/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:

CWAHI  wire general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: short circuit  Original failure mode: short to power
FAILURE RATE OR PROBABILITY  mean : 3.0E-8/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Given value is per circuit Given value is consistent with IEEE 500 data for 1000 ft circuit

CWABI  wire general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open circuit
FAILURE RATE OR PROBABILITY  mean : 1.0E-5/hr  max: 5.0E-5/hr  min: 2.0E-7/hr
Source: NUREG 2815 (table C.1.)  Ultimate source: expert judgement and IREP data
Comment:

CWAIi  wire general
Component boundary: detail n/a  Operating mode: all  Operating environment: normal
Generic failure mode: open circuit  Original failure mode: open circuit
FAILURE RATE OR PROBABILITY  mean : 3.0E-6/hr  ERROR FACTOR: 10
Source: IREP NUREG 2728 (tb.5.1-1)  Ultimate source: expert opinion
Comment: Given value is per circuit Given value is consistent with IEEE 500 data for 1000 ft circuit
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