

IEEE Standard
Reliability Data for
Pumps and Drivers,
Valve Actuators,
and Valves

Excerpted from ANSI/IEEE Std 500-1984

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Std 500-1984 P & V**

**Reliability Data for Pumps and Drivers,
Valve Actuators,
and Valves**



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Comments on standards and requests for interpretations should be addressed to:

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New York, NY 10017
USA

Foreword

The material in this volume has been excerpted from ANSI/IEEE Std 500-1984 because of specific interest in reliability data for pumps and drivers, valve actuators, and valves.

Comments are invited to this guide, as are suggestions for additional material. These should be addressed to:

Secretary

IEEE Standards Board

The Institute of Electrical and Electronics Engineers, Inc.

345 East 47th Street

New York, NY 10017

The Chairman of ANSI-FIRR at the time this guide was approved was S. W. W. Shor.

Shortly after the publication of ANSI/IEEE Std 500-1977, a series of *in-plant* visits were arranged. Team leaders and volunteers were solicited from the industry to physically collect data from maintenance records in-situ. The data are being analyzed on a continuing basis.

The first results of the in-plant reliability data system (IPRDS) effort are given in Appendix D in their respective chapters as reference [17]. The team members and participants were: L. E. Booth, S. Balestreri, R. J. Borkowski, E. P. Collins, F. Deininger, J. P. Drago, A. J. Finocchi, J. R. Fragola, J. B. Fussell, L. O. Hecht, and G. W. Jackson. Also. I. M. Jacobs, B. W. Logan, T. Luisi, F. M. Manning, C. L. Mason, A. S. McClymont, P. K. Niyogi, D. H. Pike, S. W. W. Shor, S. B. Tulloch, Jr, R. K. Turnock, and K. E. Weise.

This guide was prepared by a Working Group of Subcommittee 5, Reliability, of the Nuclear Power Engineering Committee of the IEEE Power Engineering Society.

At the time this guide was approved the members of the working group of SC5-3 were as follows:

L. E. Booth, *Chairman*

A. J. Finocchi, *Project Consultant* *

H. Rahmani, *Technical Assistant*

At the time this guide was approved the members of the subcommittee were as follows:

W. C. Gangloff, *Chairman*

Paul F. Albrecht
Andrew Barchas
L. E. Booth
F. Chamow
Kay Comer
W. K. Crowley
David Finnicum
J. R. Fragola
J. F. Fussell

Paul Haas
William Hannaman
Bruce W. Logan
Wm. J. Luckas Jr
Reginald Miles
Sati P. Mitra
Pradyot K. Niyogi
Robert L. Olson
Elmer S. Patterson

J. W. Pegram
J. R. Penland
Jim Pittman
Harry S. Reizenstein
Faust Rosa
Benjamin M. Tashjian
Mark I. Temme
Ed Wittry
J. J. Wroblewski

The data contained in this guide were collected from the data sheets and contributed by many experts and consultants. Below is a partial list of these contributors.

H. Anderson
D. Bellinger

M. C. Bryson
J. R. Fragola

C. R. Heising
H. T. Martz

*Deceased

At the time this guide was approved the members of the Nuclear Power Engineering Committee were as follows:

R. E. Allen, *Chairman*

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J. J. Ferencsik	M. Pai	J. E. Thomas
E. P. Fogarty	A. Petrizzo	T. R. Vadaro
J. M. Gallagher	E. S. Patterson	F. J. Volpe

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Jay Forster		Charles J. Wylie

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Failure Rates for Pumps and Drivers, Valve Actuators, and Valves

1. Introduction

Two of the most common components of any plant dealing with the transfer of gases, liquids and semiliquids (cement, flour, powdered coal, etc.) are pumps and valves used in nuclear, chemical, food processing, plastics, oil exploration and refining, temperature control, and concrete structure industries. Human safety, structural integrity, and energy control depend upon the reliability and maintainability of these critical items.

The data are derived from ANSI/IEEE Std 500-1984 and are displayed in generic form. They were gathered from a variety of sources and combined statistically to reduce the biases that might be introduced by overlapping sources and those with differing bases. The table of contents for each chapter has been replaced by hierarchical trees to show the manner in which the overall failure rates were generated from the original data. In general the failure rates for each subdivision were combined from the lowest bottom level to the top-most level through a succession of composites, to the final composite for the category.

1.1 Scope. This guide applies to reliability data of pumps and driver, valve actuators, and valves.

1.2 Purpose. This guide is intended to establish methods of collecting and presenting reliability data for use in reliability calculations as outlined in IEEE Std 352-1975.

The data contained in Appendix D are intended for the use of system reliability engineers or design engineers and are derived from the tables presented in ANSI/IEEE Std 500-1984. The data are normally used by design engineers in models developed by the analysts. The objectives of such models and calculations are as follows.

(1) Determination of system adequacy (failure or success probability is only one measure of system adequacy; the designer should balance reliability with other system considerations).

(2) Evaluation of system design alternatives.

(3) Evaluation of, or contribution to, the development of system test intervals, maintenance

programs or operating procedures, or both.

(4) To contribute to probabilistic risk assessment studies.

1.3 Definitions

item or equipment hazard rate. The instantaneous failure rate of an item or equipment or its conditional probability of failure versus time.

environmental application factor. A multiplicative constant used to modify a failure rate to incorporate the effects of other normal and abnormal environments.

NOTE: When available, these factors are included in Appendix D in the appropriate chapter prefaces.

failure. The termination of the ability of an item or equipment to perform its required function.

NOTE: Failures may be unannounced and not detected until the next test or demand (unannounced failure), or they may be announced and detected by any number of methods at the instant of occurrence (announced failure).

failure mechanism. The physical, chemical, or other process which results in failure.

NOTE: The circumstance that induces or activates the process is termed the root cause of the failure.

failure mode. The effect by which a failure is observed to occur.

failure mode types. (1) *Catastrophic.* A failure which is both sudden and complete.

NOTE: This failure causes cessation of one or more fundamental functions. This refers to system related failure modes. See Appendix A.

(2) *Degraded.* A failure which is gradual, partial, or both.

NOTE: Such a failure does not cease all function but compromises a function. The function may be compromised by any combination of reduced, increased, or erratic outputs. In time, such a failure may develop into catastrophic failure.

(3) *Incipient.* An imperfection in the state or condition of an item or equipment so that a degraded or catastrophic failure can be expected to result if corrective action is not taken.

outage times. (1) *Out of Service.* The average time required to get the failure, analyze it, obtain spare parts, repair and return the item or equipment to service, *including* planned delays.

(2) *Restoration.* The average time required to get to the failure, analyze it, obtain spare parts, repair, and return the item or equipment to service, *excluding* planned delays.

(3) *Repair.* The average time required to analyze the failure, repair, and return the item or equipment to service. This excludes planned delays and waiting for spares or tools.

failure rate. The expected number of failures of a given type, per item, in a given time interval (for example, valve failures per million valve hours).

NOTE: For *cyclic* items or equipment insert "in a given number of operating cycles."

operating conditions. The loading or demand cyclic operation, or both, of an item between zero and 100% of its related capability(ies).

operating time. The period of time that an active item or equipment is functioning effectively.

component. The largest entity of hardware for which data are most generally collected and expected to be available (for example, pump with motor, valve with operator, amplifier, pressure transmitter). It is generally an off-the-shelf item procured by the system designer as a basic building block for his system. It should be distinguished from seals, materials, nuts, bolts, and other piece parts from which the component is made.

system. A collection of components arranged to provide a desired function (for example, containment spray system, residual heat removal system, high pressure coolant injection system).

fault. Any undesired state of a component or system. A fault does not necessarily require failure (for example, a pump may not start when required because its feeder breaker was inadvertently left open—a "command fault").

failure. A subset of a fault and represents an irreversible state of a component such that it must be repaired in order for it to provide its design function. A component failure is generally defined in terms of the system in which it resides. For example, any leak might be considered a failure in a system where fission products are to be contained, and yet leaks may be

considered as normal or even required states of other systems (for example, pump packing gland leakage). Failures are sometimes classified as either primary or secondary.

(1) A *primary failure* is the so-called "random failure" found in the literature. It results from no external cause.

(2) A *secondary failure* results when the component is subject to conditions which exceed its design envelope (for example, excessive voltage, pressure, shock, vibration, temperature).

common cause failure. Two or more redundant component failures due to a single cause. The common cause events that cause multiple failures are usually secondary events or events which exceed the design envelope of the component.

demand failure rate. The probability (per demand) of failure that a component will fail to operate upon demand when required to start, change state, or function.

operating failure rate. The probability (per hour) of failure for those operating components required to operate or function for a period of time.

standby failure rate. The probability (per hour) of failure for those components which are normally dormant or in a standby state until tested or required to operate to perform their function.

1.4 General. The areas considered in the preparation of the tables of this guide are listed below:

1.4.1 Common Time or Cycle Base. To ensure uniform interpretation, the failure data of all items and equipment have been reduced to a common time or cycle base. Because failures are relatively few, they are estimated for each item or equipment in failures per million hours of operation or in failures per million operating cycles. In each case, upper and lower subjective bounds (expressed as a range) have been established for estimated data, and a 90% confidence interval has been established for statistical data.

1.4.2 Source and Scope of the Failure Data. The sources from which the data were compiled are listed in Appendix C. Failure and outage data obtained from published sources are acknowledged and referenced.

1.4.3 Plant Environment. Consideration of actual plant environments in various plant areas

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and various operating conditions is routinely required in the course of an analysis. In these instances, the appropriate environmental factors, when available, should be applied to the listed failure rates. Specific consideration should be given to an item or equipment which is required to be operable during and after an accident.

1.4.4 Constant Hazard Rate. In all cases, the individual item or equipment hazard rate is assumed constant. Any significant deviations from a constant hazard rate are noted.

1.5 Failure Mode. This guide concentrates on failure modes of items of equipment as described in Appendix A. These failure modes are recorded next to each item or equipment description in the data sheets of the tables.

1.6 Limitations of Data. The user should be aware of certain limitations of the data contained in the tables of this guide. Foremost is that the failure rate reported here is not always developed from an actual count of failures in one or more plants. It has sometimes been developed from a wide range of applications which include fossil-fueled power generating stations and industrial process plants but which are applicable as data sources for reliability analysis.

The data for Ref. 1 resulted partially from the analysis of estimates made by over 200 experts. These estimates were collected by an extensive multistep Delphi survey. Therefore, in some cases, the data developed represent either recorded data or the best collective judgment of a group of specialists.

No claim is made the IEEE standard document for pumps and drivers, valve actuators, and valves represents a random sample of plants. Therefore, both the recommended (REC) values (the geometric means or "best estimates") and the interval reported may be expected to differ from those experienced in-service for some of the failure data reported.

The published failure data values given in the guide are for items used under the conditions discussed in individual references and sources. They are intended to apply only to such use. The user should take appropriate precautions while applying these data under different conditions.

The reliability of an item tends to increase as the applied stresses (such as electrical, mechanical, and environmental) decrease, and vice versa. The user is cautioned to consider the effect of operating conditions in the plant prior to the use of the data contained herein.

2. Data Processing

2.1 Data Processing for Pumps, Valve Actuators and Valves. In most cases, the minimum and maximum values given in the tables represent the geometric means of individual values obtained from various sources. As such they should be interpreted as ranges and not as specific confidence bounds. However, in some specific cases (discussed in 2.3), *low* and *high* values are the 90% confidence interval around the best estimate.

In the analysis and pooling of the failure-rate estimates, care should be taken to ensure that the analytical techniques are no more sophisticated than the pool of estimates to which they are applied.

Therefore it was decided that the simple procedure of unweighted geometric averaging was preferred for the first edition. This was based on the subjective observation that the distribution of estimates was better represented by failure-rate exponent averages than by mantissa averages.

Given

$\hat{\lambda}_{\min, i}$ = individual estimate of minimum failure rate

$\hat{\lambda}_{\max, i}$ = individual estimate of maximum failure rate

$\hat{\lambda}_{b, i}$ = individual best estimate of failure rate

n = the number of individual estimates

The geometric averages are obtained using the following equations:

$$\hat{\lambda}_{\min} = \text{anti-log}_{10} \left[\frac{1}{n} \sum_{i=1}^n \log_{10} \hat{\lambda}_{\min, i} \right]$$

$$\text{or} \quad \left[\prod_{i=1}^n \hat{\lambda}_{\min, i} \right]^{1/n}$$

$$\hat{\lambda}_{\max} = \text{anti-log}_{10} \left[\frac{1}{n} \sum_{i=1}^n \log_{10} \hat{\lambda}_{\max, i} \right]$$

$$\text{or} \quad \left[\prod_{i=1}^n \hat{\lambda}_{\max, i} \right]^{1/n}$$

$$\hat{\lambda}_b = \text{anti-log}_{10} \left[\frac{1}{n} \sum_{i=1}^n \log_{10} \hat{\lambda}_{b, i} \right]$$

$$\text{or} \quad \left[\prod_{i=1}^n \hat{\lambda}_{b, i} \right]^{1/n}$$

where

$\hat{\lambda}_{\min}$, $\hat{\lambda}_{\max}$, and $\hat{\lambda}_b$ = accepted combined estimates of the minimum, maximum, and most likely (best estimate) failure rates, respectively.

This heuristic technique has been useful in Delphi pollings, such as this one, where a consensus is sought on several properties of a distribution for a random variable. Since Delphi procedures deal, in part, with opinion (not exclusively recorded information) they are not purely statistical procedures.

Where recorded data was available it was combined with the Delphi results by the same heuristic technique.

2.2 Data Processing for IEEE Pump and Valve Failure Rate Document. The 1984 edition of IEEE Std 500 has separate entries for each data source including ANSI/IEEE Std 500-1977 which is designated in Appendix C as reference [1] for data source. The separation of the data entries allows the user to combine data by any method deemed appropriate.

When combining the data, two factors should be kept in mind;

(1) Since data sources such as Licensee Event Reports (LER) data summaries, Nuclear plant reliability data system (NPRDS), and Inplant reliability data system (IPRDS) often report on the same nuclear plants then not all the data points are statistically independent

(2) ANSI/IEEE Std 500-1977 contains information obtained by way of Delphi process and published data sources, thus it cannot be treated properly without consideration of bias due to expert opinion [1].¹

For the purposes of this edition, a weighted geometric means was chosen as the maximum likelihood (ML) estimator.

The maximum likelihood (ML) estimator is determined by the following modification of the geometric mean as described in [1].

$$\hat{\theta} = \prod_{i=1}^n \hat{\theta}_i^{W_i}$$

where

$\hat{\theta}$ = the ML of failure rates or outage times

i = data source number, 1, 2, 3...

W_i = a dispersion dependent weighting factor for each data source

and

$$W_i = \frac{\sigma_i^{-2}}{\sum_{i=1}^n \sigma_i^{-2}}$$

where

σ_i^{-2} = reciprocal of the variance of the log of each data source

If the available measure of dispersion are ranges only, a suitable function of the ranges can be substituted for σ_i^2 .

The weighting factor W_i is important because it reduces the influence of data sources with large ranges and vice versa it increases the impact of data with narrower ranges. Data sources with wide ranges of course indicate insufficient data or data from an immature data base. Likewise, for Delphi data, experts with less confidence in their estimates tended to give wider ranges. Wider range Delphi information thus carries less weight than it would in a simple unweighted geometric mean approach.

There are cases where no measure of dispersion is available. In these cases, the maximum likelihood estimator $\hat{\theta}$ was determined by taking the unweighted geometric mean for all data points not having measures of dispersion and combining that result with the others by the following relation,

$$W_j = \frac{j}{(j+k)}$$

where

W_j = weighting factor with dispersion

j = number of data points with dispersion

k = number of data points without dispersion

$$W_k = \frac{k}{(j+k)}$$

W_k = weighting factor without dispersion

$$\hat{\theta}_{j,k} = \hat{\theta}_j^{W_j} \hat{\theta}_k^{W_k}$$

= weighted geometric mean for combined observations with and without measures of dispersion

2.3 Statistical Data from a Single Population.

In some cases, data were available which were amenable to statistical treatment. If the data came from a single population with a failure rate λ (exponential density), it was treated as a x^2 distribution (see [2]). It has also been shown in [3] that the x^2 distribution can be used to construct confidence bands. In particular, IEEE Std 352-1974 gives the confidence interval on λ data as

$$\frac{x^2 \alpha / 2; 2n}{2T^*} \leq \lambda \leq \frac{x^2 1 - \alpha / 2; 2n+2}{2T^*}$$

¹The numbers in brackets refer to the references in Section 4.

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where

n = number of failures observed

α = 1 - confidence level desired

The recommended value of λ is

$$\hat{\lambda} = n/T^*$$

T^* = accumulated item or equipment test or operating hours over a fixed calendar time.

The associated upper and lower confidence bonds on λ are given by:

$$\lambda_L = \frac{x^2 \alpha/2; 2n}{2T^*} \text{ and}$$

$$\lambda_u = \frac{x^2 1 - \alpha/2; 2n+2}{2T^*}$$

where

λ_L and λ_u = lower and upper bonds, respectively.

The value of x^2 can readily be obtained from standard tabulations [4] and [5] for the cases where the problem degrees of freedom ν are less than 30, and by the following approximation for $\nu > 30$:

$$x^2 = \frac{1}{2} \left[(2\nu - 1)^{1/2} + Z \right]^2 \quad [6]$$

where

Z = value of the standard normal variable at the desired confidence interval and where the number of degrees of freedom is given for the upper and lower bonds by:

$$\nu_L = 2n$$

$$\nu_u = 2n + 2.$$

The procedure used for establishing the data base and calculating the component failure rate is as follows: From the plant equipment lists, piping and instrument diagrams, and process flow diagrams, a population card was formulated for each component containing information such as the component identification number, system, and type, type of operator, process fluid, and size. System codes were assigned from descriptive information derived from plant equipment lists and piping & instrument drawings (P&ID's).

The failure rate estimate is calculated after determining the appropriate numerator (number of failures) and denominator (component hours or demands) from the data base. To determine the numerator of the failure rate estimate, the analysts reviewed all the corrective maintenance records collected from the plant visit for related failures. These records were separated, reviewed again, and classified. Analyzing the failure and repair text, the analysts assigned the following codes: failure cause(s), failure severity, and failure mode. The data reported on the maintenance record such as

component name, failure date, failure and repair text, as well as the code assignments from the analyst were entered into the computer. A computer program then matched the individual failure and repair record with the population record on the basis of the component identification number. A population record/failure and repair record set was thus generated for each population record, containing the failure and repair history of each component. The total number of failures for a particular component of interest was used as the numerator for the failure rate estimate. Information was gathered to determine the denominator of the failure rate estimate: the total number of service hours for a time-dependent failure rate or the total number of demands for a demand failure probability. For each component analysts assigned the service hours (calendar hours in the system) and an estimated number of demands (12 actuations per year) to each component.

3. Data Format

The format for the presentation of the data is shown in Fig 1. The following paragraphs describe the sections of the format. A detailed description of the data sheets and hierarchical development is found in each chapter of Appendix D.

3.1 Chapter. The chapter identifies the broadest hierarchical breakdown (for example pumps, valves, actuators and valves.)

3.2 Section. The section is the second level of the hierarchy. The bases for the divisions vary from chapter to chapter but are usually based on functional or physical differences.

3.3 Subsection. The subsection is the third hierarchical level. In those instances where data are collected to only this level, the subsection is located in the item or equipment description.

3.4 Item or Equipment Description. The item or equipment description may represent the third or fourth hierarchical level. In those instances where the subsection is left blank, the description represents the third level. In all other times it represents the fourth level.

3.5 Failure Mode. This column contains a brief description of the manner in which the failure occurred (where such information was available). A further discussion of failure modes is presented in each chapter preface and in Appendix A.

3.6 Failure Rate. The failure-rate columns present various values of the failure-rate range. The low and high values establish the range, and represent, respectively, the best and worst data points. The recommended values (REC) should be used to determine the best estimates and the high and low values can be used as range estimates.

Two types of rates are presented: failure per 10^6 hours and failures per 10^6 cycles. The cyclic failure rate is used in specific instances to describe demand probabilities as noted in each chapter.

3.7 Outage Times. Outage times are divided into three separately entered categories; out of service, restoration (designated as restore), or repair. All time entries are in hours. The low and high columns represent the highest and lowest observed data points. The outage times are designated *, § or † respectively in each chapter data sheet of Appendix.

3.8 Reference. The reference (REF) column identifies the origin of the data given in the data source reference section of Appendix D.

4. References

- [1] MARTZ, H. F. and BRYSON, M. C., *A Statistical Model for Combining Biased Expert Opinions*, Los Alamos Report LA-UR-83-531. Los Alamos Scientific Laboratory, PO Box 1663, Los Alamos, New Mexico 87545.
- [2] EPSTEIN, B., *Tests for the Validity of the Assumption that the Underlying Distribution of Life is Exponential*. Technometrics. Feb and May 1960.
- [3] MILLER, I., and FRUEND, J., *Probability and Statistics for Engineers*. Englewood Cliffs, NJ: Prentice Hall, Inc, 1965, p 373.
- [4] MANN, N. R., SCHAEFER, R. E., and SINGPURWALLA, N. D., *Methods for Statistical Analysis of Reliability and Life Data*. New York: John Wiley and Sons, 1974, ch 9, pp 119-164.
- [5] *Biometrika*, vol 32 (1941-1942).
- [6] CALABRO, S. R., *Reliability Principles and Practices*. New York: McGraw Hill, 1962.

Fig 1
Typical Data Report Sheet

CHAPTER:	SECTION:	SUBSECTION:										
ITEM OR EQUIPMENT DESCRIPTION												
FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				

Appendixes

(These Appendixes are not a part of IEEE Std 500-1984, IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear-Power Generating Stations.)

Appendix A

A Discussion of the Term *Failure Mode*

A1. Introduction

Failure terms are usually assumed to be so well understood that they do not necessarily require definitions. They are seldom questioned in everyday usage. Even in formal test plans and procedures *failure* usually can never be so well defined as to avoid debates on some of the anomalous events which can occur in the testing or performance evaluation of materials, components, items, equipment, personnel, or complex systems, or a combination of these. Therefore, to establish a definition for *failure mode*, an examination of the concepts of failure as they relate to the testing and operation of systems, equipment, personnel, parts, and materials must be undertaken.

A2. Failure Concepts

Failures of hardware may be defined perhaps most commonly in abstract functional terms such as: *the loss of ability (or inability) to perform a required function (or functions)*. Failures of an operator may be defined on such terms as: (1) *noncompliance with established procedures*; (2) *improper actions (or improper inaction)*; or (3) *operator error*, or a combination of these. Failures of equipment or materials may be defined technically in terms of definitive specification parameters which were not met during established tests or inspections. Failures of complex systems may be defined in terms of system functions which are disabled or degraded by the failure. These failures may also be defined in terms of the degradation or loss of specific functions by the subsystem in which the failure occurred. In tracing a system failure to the lowest level of assembly or part involved in the failure event there will often be a chain of interrelated events (or failures) — each of which had an effect upon another element (or elements) in the chain.

A3. Failure Types

A3.1 Statistical Types. Some types of failures are classified on the basis of the statistical distributions representing their frequency of occurrence. These include the exponentially — distributed *random* failures, having a *constant* hazard rate; and, the Gaussian or Weibull — distributed *wear out* failures, having an increasing hazard rate. The only statistical type of failures used in Appendix D is the *constant* hazard rate.

A3.2 Failure Tracing Types. In tracing system failures, often a *primary, independent*, or root-cause failure (which initiated a series of events leading to the failure of the system) and one or more *secondary, dependent*, or contributing failures. These are failures which were caused directly or indirectly by the root-cause failure.

When discussing failure tracing it is helpful to characterize failure causes as root causes, contributing causes and immediate causes. Briefly, a root cause can be characterized as the basic or fundamental cause of a failure. Root cause should not be confused with *failure mechanism* (see A4). These are generally a myriad of contributing causes that lead to the failure. Contributing causes follow root causes and lead up to an immediate cause. The immediate cause is the cause that immediately precedes the failure mode (see Fig A1).

A4. Failure Mechanism

The failure mechanism defines the physics of the failure. This involves the description and sequence of those mechanical, electrical, or chemical processes or a combination of these, which occurred during the period in which the failed item changed from an operational item to a failed item. For example, electrical or mechanical overloads which involve a level of

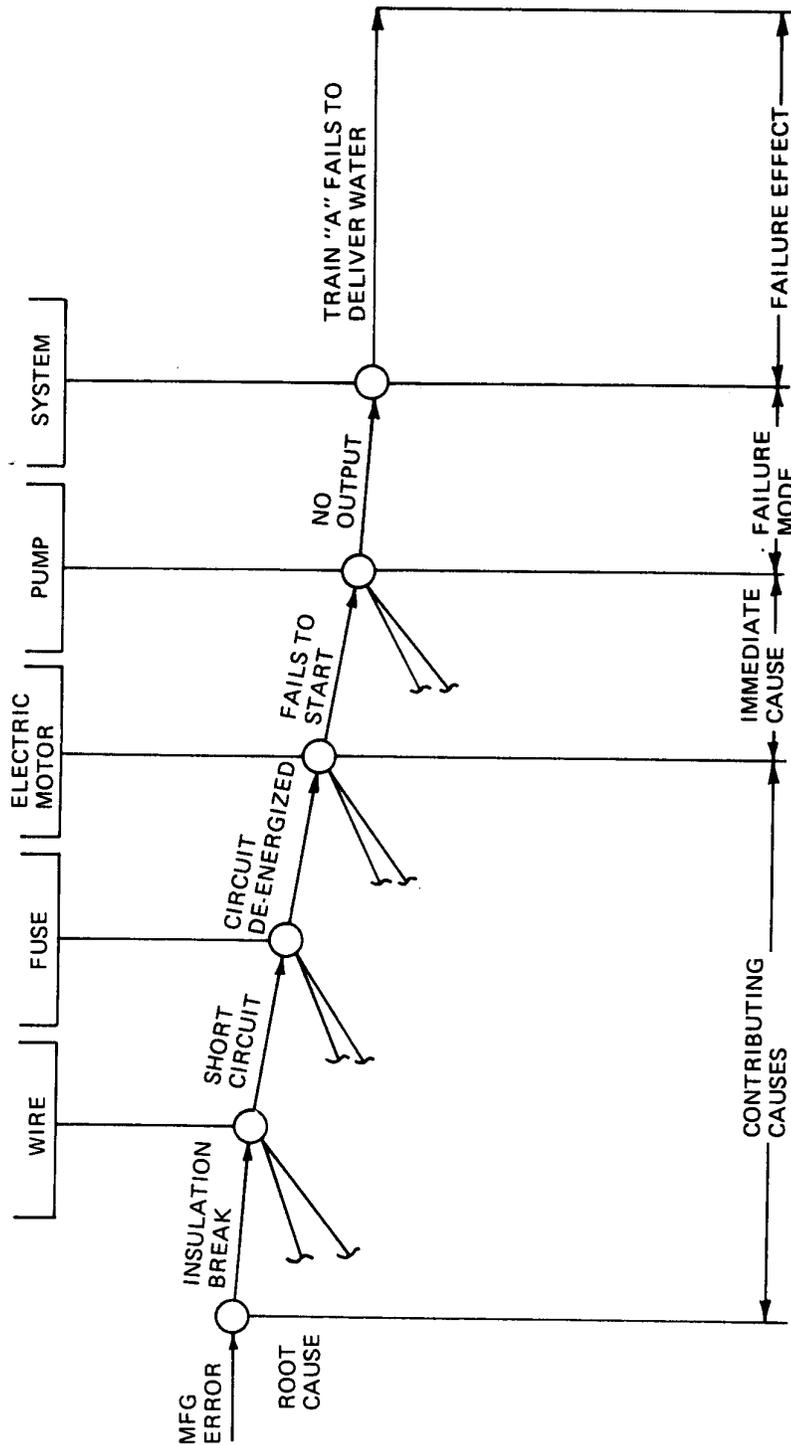


Fig A1
The Relationship of Failure Causes, Modes, and
Effects for a Pump

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stress which exceeds the rated electrical or mechanical strength of an item will cause physical damage resulting in loss of functional capability. The failure mechanism is the process which occurred to change the physical or functional characteristic, or both, of the materials in the failed item (for example, *relay coil wire burned open by electrical overload*).

A5. Failure Modes

When failures occur in a system element they often occur in a variety of ways. For example, a relay can fail in the closed position (for example, when contacts are welded shut) or the open position (for example, when contacts fail to close on demand because of such problems as an open coil). A *failure mode* is defined as: *the effect by which a failure is observed to occur* and is usually characterized by description of the manner in which a failure occurs. It is a description of the failure itself. A failure mode provides a descriptive characterization of the failure event in generic terms — not in terms of the *failure mechanism*: which occurred, and not in terms of the *failure effect* (see below). In the case of a relay which fails to close on command, the failure mode is *fails to open or fails to close*.

An important thing to recognize in defining a failure mode is that each failure mode must be defined and considered at a particular indenture level (that is, a failure mode at the part level usually has an effect upon a higher-level of indenture which, in turn, may be involved in another, different failure mode) (as shown in Fig A1). This is the so called system-related failure mode approach as described in Appendix A of ANSI/IEEE Std 500-1977.

A6. Failure Effects

The effects of a failure within a system may be propagated to higher and lower levels of assembly — or the system design may prevent such propagation. The propagation and interrelationships of failure modes and failure effects have

been well illustrated in such documents as the PRA Procedures Guide vol 1 (NUREG/CR-2300). Failure mode and effect analysis is a formal approach to the analysis of failure modes and their propagated effects involves the loss or degradation of functions and also the effects of failures on system safety (that is, hazards to personnel, or property, or the environment, or a combination of these). In a typical system, failure of a part affects the function of the assembly of which it is a part. This *effect* also initiates a *failure mode* at the assembly level. The *effect* of this assembly *failure mode*, in turn becomes a *failure mode* at the next higher level (for example, the subsystem). Therefore, as failure modes and effects occur at successively higher levels of indenture each *failure effect* may give rise to a new *failure mode*. In the operational and maintenance man-machine interfaces, the common failure syndroms (that is, failure indications) are usually identified by some established terminology (for example, Loss Of Cooling Accident, LOCA).

A7. Development of Failure Modes

The purpose of the tables is to present failure and repair information, therefore it should not be interpreted as a failure reporting, failure investigation, or cause tracing tool; that can only be accomplished by carefully researching the referenced data sources.

The failure modes shown in the tables are a brief description of the manner in which the failures occurred as reported in the data sources. So as to make the reported descriptions consistent from one data source to another, failure modes were reworded on a common basis. For instance, *functioned without a signal* and *false trip* were replaced by *spurious* response. In the case of pumps, *failed to run once started* and *failed to continue to run* were replaced by *failed to run* since *failed to start* was already a part of the failure mode description. In general the failure modes are similar if not identical to those shown in Figs A2 and A3.

		Failure Severity		
		Catastrophic	Degraded	Incipient
Change in item or equipment condition	Change in operation	<ol style="list-style-type: none"> 1. Failure to operate (run) 2. No output 	<ol style="list-style-type: none"> 1. Low output 2. High output 3. Erratic output 4. Locked in one mode of operation 5. Output above or below specified requirements 	<p>Discovered through:</p> <ol style="list-style-type: none"> 1. Local inspection (overheating, leaks, contamination, noise, severe vibration, odor, cracks, etc) 2. Testing: (output above or below specified limits while in stand-by mode of operation) 3. Monitoring (trend towards failure)
	Change of state	<p>Change without demand</p> <p>A spurious:</p> <ol style="list-style-type: none"> 1. Start/Stop 2. Insertion 3. Withdrawal 4. Actuation 5. Response 6. Opening 7. Closing 	<ol style="list-style-type: none"> 1. Premature or delayed actuation (an actuation that occurs out of timing sequence) 2. Won't stay open or closed 	<p>Discovered through:</p> <ol style="list-style-type: none"> 1. Testing: Failure or diminished ability to transmit or retain energy during the stand-by mode of operation 2. Local inspection
	No change on demand	<p>Failure to:</p> <ol style="list-style-type: none"> 1. Start 2. Stop 3. Insert 4. Withdraw 5. Actuate 6. Respond to command 7. Open 8. Close 	<p>Improper Response:</p> <ol style="list-style-type: none"> 1. Partially open, close, etc 2. Oscillation (failure to assume a fixed position) 	

Fig A2
Failure Mode Matrix
Active Item or Equipment

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		Failure Severity			Incipient
		Catastrophic	Degraded		
Change in item or equipment condition	Failure to retain or transmit energy	Diminished ability to retain or transmit energy	Change in operation		(1) Testing: Failure of diminished ability to transmit or retain energy during the energized mode of operation (2) Local inspection (leaks, vibration, odor, cracks, etc) (3) Monitoring: Monitoring trend towards failure, during the energized mode of operation
	1.0 Breach of pressure or static fluid boundary	1.0 Degradation of pressure or static fluid boundary			
	1.1 Major leaks	1.1 Minor leaks			
	1.1.1 External leaks	1.1.1 External leaks			
	1.1.2 Internal leaks	1.1.2 Internal leaks			
	1.2 Explosions	2.0 Interference with energy transport or exchange capability			
	1.3 Implosions	2.1 Restricted flow			
	2.0 Loss of energy transport or exchange capability	2.2 Reduced heat transfer capability			
	2.1 Blocked or stopped flow	2.3 Minor heat loss			
	2.2 Loss of heat transfer capability (scale buildup)	3.0 Structural integrity compromised			
	2.3 Major heat loss (loss of insulation)	3.1 Reduced support capability			
	3.0 Loss of structural integrity	3.1.1 Fracture of part of the structural members			
	3.1 Failure to support or brace	3.1.2 Minor physical distortion			
	3.1.1 Fracture (of all members)	3.2 Partial failure to fasten or join			
	3.1.2 Physical distortion (permanent set)				
	3.1.3 Distortion under load (without perm. set)				
	3.2 Failure to fasten or join				
	3.2.1 Removable fastener failure				
	3.2.2 Failure of permanent joint				
	3.2.2.1 Weld failure				
	3.2.2.2 Imbed failure				

Fig A3
Failure Mode Matrix
Passive Item or Equipment

Appendix B The Delphi Procedure

This guide utilized a Delphi procedure (see [1],² to secure from over 200 experts located throughout the county, initial failure-rate and failure-mode estimates on components used in the power industry. Since nuclear plants are historically reliable (the total of equipment failures is well under 300 a year) it was impossible to secure estimates of failure rate by relying exclusively on plant operating failure data. However, even though operating data were not specifically available, information existed throughout the industry in various forms. It was known that published data sources existed external to the industry which might be to some degree applicable. During the course of the Delphi procedure the working group examined published data sources not only in the power apparatus and instruments industries but also in aerospace and other industries.

Thus the data from which Appendix D was synthesized were found in the following forms:

- (1) Statistical operating data from nuclear facilities.
- (2) Statistical operating data from fossil-fired generating stations and other large industry data (such as the chemical industry).
- (3) Statistical failure data from transmission grids and industrial plants with judgment used to estimate the population from which the failures were observed so that a failure rate could be calculated.
- (4) Failure and population estimated data made 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 nuclear-power generating station components.

It should be noted that individual experts were instructed to generate estimated data only when statistical sources of data remained unavailable to them.³

²The numbers in brackets in Appendix B refer to the references in B4.

³On the average, 80% of the data included in the document resulted from statistical data falling into one of the first three categories given above.

B1. Use of the Delphi in the Development of Ref [1]

Individuals familiar with the failure modes and failure rates in the power industry are usually specialists on a certain range of equipment that represents but a small segment of the components in any power plant. In addition, the number of experts available to participate in estimating failure rates for some of the specialized equipment might be small. However, much of this knowledge resides in the years of experience on the part of these specialists. Therefore:

- (1) Over a hundred individuals were needed for coverage of the scope of components in a nuclear power plant.
- (2) Only a small number of individuals have direct knowledge of any one subset of components. These small groups of individuals are not unique: for example, there may be overlapping memberships.
- (3) Much expert judgmental data had to be integrated.

The unique nature of the problem dictated that a specific Delphi approach be taken from established principles of the Delphi method outlined in B3. The objectives of this approach as applied to the document were to:

- (1) Develop a logical structure for consideration of all the components in a nuclear-power generating station and for their modes of failure. (See B2.1.)
- (2) Solicit reliability data, or estimates, or both, for components on the first Delphi round while allowing respondents to further develop possible modes of failure on the forms indicated in B2.2.
- (3) Solicit on the second round, estimates of newly defined failure modes and reliability data for any additional components.
- (4) Solicit, on the third round, re-examination of any areas where there appears to be significant polarization of disagreement among those responding to a particular question. Solicit evaluation of the magnitudes and range of relevant published data.
- (5) Solicit, on the fourth round, any final changes in component reliability data, or estimates, or both, that the respondents desire.
- (6) Retain at all times the anonymity of re-

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spondents so that responses are not misrepresented as reflecting an organization in which the particular respondent may be employed.

(7) Structure the procedure and questions so that only those specializing in a particular set of components will respond to that set.

Over 150 professionals provided input as chapter administrators, experts, and consultants. These primary respondents were encouraged to utilize colleagues and associates as they deemed necessary or desirable to broaden the scope of the response.

To further refine the results of the responses, it was recognized that the performance of a Delphi group increases as its collective expertise increases. This fact includes within it the subtle problem of discovering an independent measure of expertise. Several approaches to the solution of this problem have been proposed. See [1]. Of the approaches investigated only those of ordinal self-ranking were considered to be of any practical value. This method was employed by the Delphi experts on an individual basis using a scale of 1 to 5. Experience dictated that when estimates occur in the tails of distributions, the estimators responsible usually rated their expertise lower than those within the mean of the group, and even this result did not occur very often. Also, by the very nature of the experts selection process, most of the participants were judged *a priori* by their peers to be in the 4 or 5 category. In actuality, the experts ranked themselves for the most part as either a 4 or a 5. Thus, the expert weighting of the data did not essentially change the results which would have been obtained from an unweighted group.

B2. Delphi Questionnaires

B2.1 Pre-Questionnaire Period. The pre-questionnaire period exhibited activity at all levels of the organization. The project administration developed a general questionnaire form and the instructions for its use. A schedule was established for completing the Delphi, and the Delphi technique, and the use of the forms was explained to the chapter administrators. The project administration also assisted and guided the chapter administrators in the preparatory work leading to the Delphi.

B2.2 First Round Questionnaire. Chapter administrators issued their modified questionnaire forms (Fig B1) to the Delphi experts, and they explained the use of the form. The Delphi experts were free to use any data sources in answering the questionnaires. Those most commonly used sources were recorded data from the expert's company or personal files, personal experience, and published data. The experts also added any comments and suggestions that they considered were pertinent. The questionnaires were then returned to the chapter administrators. The chapter administrators collected the completed questionnaires, evaluated the suggestions and comments, and sent the forms to the project administration. The comments provided valuable supplementary information about the various equipment types. These comments were evaluated and edited by the chapter administrators and are given in the chapter prefaces. The completed forms and suggestions for improvements were sent to the project administration, which, in turn, had experts from the data processing chapter evaluate, compile, and display the data.

B2.3 Second, Third, and Fourth Round Questionnaires. The second generation Delphi questionnaire (Fig B2) was developed by the project administration and was based upon the development plan and comments from the first questionnaire. The chapter administrators again modified the general questionnaire form to make them unique to their chapters and sent the forms and the compiled data to their experts. Experts were given the opportunity to either reaffirm or change their previous estimates, based upon the compiled results from the first questionnaire. The process from this point was identical to that in the first questionnaire. The pattern repeated itself through the fourth questionnaire with the specific exceptions discussed in B2.1.

B2.4 Post-Questionnaire Period. Only the project administration and data processing chapter personnel were active during the post-questionnaire period. They analyzed and compiled the questionnaires from all the rounds, correlated the data, and tested them against existing data sources. When completed, the data were placed into the failure rate tables of Appendix D.

(1) Estimated Failure Rate Under Operating Applications Min _____ Best Est _____ Max _____ (fail/10⁶ hrs)
 (2) Estimated Failure Rate Under All Applications Max _____ (fail/10⁶ cycles)

(3) Type of Experience _____

(4) Rate Your Expertise (Overall) _____
 1 = Low
 5 = High
 6 = Recorded Data

(5) Estimate Based on Recorded Data? If so, indicate:
 Source of Data _____
 Number of Operating Hours _____
 Number of Failures _____

(6) Failure Modes	(7) Mode Percentage	(8) Environmental Factors			(9) Rate Your Expertise (Failure Modes)
		High Temperature	High Radiation	High Humidity	

(10) Rate Your Expertise (Environmental Factors) _____

(11) Questions/Comments: _____

IEEE Project 500 — Initial Delphi Failure Rate Estimate Format
 Fig B1

<p>(1) Estimated Failure Rate Under Operating Applications</p> <p>Min _____ Best Est _____ Max _____ (fail/10⁶ h)</p> <p>Min _____ Best Est _____ Max _____ (fail/10⁶ cycles)</p>	<p>(2) Estimated Failure Rate Under All Applications</p> <p>Min _____ Max _____ (fail/10⁶ h)</p> <p>Min _____ Max _____ (fail/10⁶ cycles)</p>
<p>(3) Type of Experience _____</p>	
<p>(4) Rate Your Expertise (Overall) _____</p> <p>1 = Low 5 = High 6 = Recorded Data</p>	
<p>(6) Failure Modes _____ Mode Percentage _____</p>	
<p>(5) Basis for Estimate Source of Data (If Applicable) _____</p> <p>Cumulative Number of Operating Hours (On both failed and unfailed components — parts x number of hours) _____</p> <p>Number of Failures _____</p> <p>Population _____</p>	
<p>(8) Environmental Factors</p> <p>A factor less than 1 decreases the rate A factor equal to 1 does not change the rate A factor greater than 1 increases the rate</p> <p>High Temperature _____</p> <p>High Radiation _____</p> <p>High Humidity _____</p> <p>Other (Identify) _____</p>	
<p>(9) Rate your Expertise Failure Modes _____</p> <p>Environmental Factors _____</p>	
<p>(10) Questions/Comments: _____</p>	

Fig B2
IEEE Project 500 — Modified Delphi Failure-Rate Estimate Format

B3. The Delphi Method

The *Delphi method* (see [1]), represents the concept of establishing a feedback system for the written communication of data and information among a group of professionals. It characteristically involves:

- (1) A group of specialists or experts on the topic of concern and an administrative team needed to carry out the exercise.
- (2) The design of a structure that focuses on the nature of the problem being considered.
- (3) A series of questionnaires that utilize the overall structure in terms of specific issues or data.
- (4) Anonymous response to the questionnaires on the part of the respondents.
- (5) An opportunity for respondents to revise judgments based upon summaries of the group's response prepared by the administrative team.
- (6) Anywhere from two to five iterations of the material through the questionnaire — summary — revision — new questionnaire process.

The Delphi method is, therefore, a technique to solicit, synthesize, and correct or improve individual and group judgment. The concept was developed in the 1950s by the RAND Corporation. See [2] and [3]. Studies using the Delphi method have been conducted on groups from five to five hundred in size. There have been over five hundred published reports on Delphi exercises, and it is estimated that proprietary studies using the Delphi method conducted in corporations represent over two thousand additional studies.

A number of successful applications have been documented in a recent book (see [1]) together with criteria and guidelines on the design and application of Delphi.

Those active in the area currently view Delphi as a communication process structured around a particular problem. Studies using the Delphi method have been implemented by way of computer terminals as well as by paper and pencil. A major justification for the technique lies in the fact that in many situations so-called *classical* statistical data do not exist, and for many information gathering efforts other communication schemes are impossible. Typical reasons which invalidate other schemes are: group size, travel costs, time constraints or psychological bias, or both, or organizational problems.

In the case of Appendix D, the need for statistical failure rate estimates has long been realized by the nuclear industry and its government regulators. Since the standardized collec-

tion and statistical analysis of historical data has not been centrally organized, any project which relies upon *classical data* alone cannot hope to provide failure rate information broken down to the level of sophistication presently required by the industry. However, the industry has long recognized that, despite its isolation, a wealth of valuable data is available even today. These data are locked up in the years of personal experience of hundreds of experts. The Delphi provides a procedure that finally allows this valuable resource to be tapped for the benefit of all parties concerned.

Typical ways to gather this information is to:

- (1) Interview every one of these individuals at least twice to establish consistency among differences in responses.
- (2) Hold many hundreds of small group meetings with associated travel costs and assume all the experts are able to give the time involved.
- (3) Launch a wide number of small studies with the organizations employing these specialists.

The first two approaches are prohibitively expensive to conduct and the last is impractical because the individuals in a particular area are not unique to any one organization. Most of the experts involved have severe constraints on available time. Therefore, the Delphi appeared to be the only mechanism available for gathering reliable information in an efficient and timely manner. The resulting emphasis of the Delphi is that of an exercise where the specific knowledge of small groups of respondents is tapped, but within the context of an overall structure.

As a result of the above conditions and the value of the specific data being collected, these particular data do not suffer from some of the difficulties facing those exercises that deal with broad concepts and heterogeneous mixtures of expertise.

B4. References

- [1] LINSTONE, H. A. and TUROFF, M. *The Delphi Method: Techniques and Applications*. Addison-Wesley Inc, MA, 1975.
- [2] DALKEY, N. and HELMER, O. An Experimental Application of the Delphi Method to the Use of Experts, *Management Science*, vol 9, 1968.
- [3] DALKEY, N. and HELMER, O. *The Use of Experts for the Estimation of Bombing Requirements — A project Delphi Experiment*. The RAND Corporation, Tech Rep RM-728-PR, Santa Monica, CA, Nov 1951.

Appendix C

Development of the Hierarchical Trees and Limitations of the Individual Data Sheet Entries

Although every effort has been made to make the tables uniform and consistent, there are exceptions that are worth noting. This includes the general philosophy behind the development of the hierarchical trees that is given in each chapter preface.

The relationship of differences in failure rates to differences in design configurations has been apparent in most reliability data bases in recent years. However, many other factors influence that difference. Early documents did attempt to identify factors other than design differences and incorporate those factors into the generic hierarchical structure. Subclassification of equipment by voltage is one such example.

Two new factors influence the hierarchical structure. First, outage times (particularly repair times) tend to be related to size. Second, presently available data sources contain a mixture of information as to size, application, and design configuration. Some data sources only describe the equipment in terms of size or application, or design configuration, but not in any combination of the three. Thus, so as to use some data sources a new conversion for the development of hierarchical structures was necessary.

C1. Alpha Numeric Indexing of the Hierarchical Trees

Previous documents used the same numeric indexing method as is commonly used in report writing so as to uniquely identify various levels of the generic hierarchy.

It has become clear that a purely numerical method of indexing was not practical when combining various data sources into one *composite* because there is not uniform way to distinguish size, application, and design configuration which would not vary from chapter to chapter. To avoid this potential source of con-

fusion, an alpha-numeric system was adopted which designates the size category as (a), the application category as (b) and the design difference category as purely numeric. For a hypothetical "chapter 30" hierarchical tree shown in Fig C1 would provide the framework for the organization of the data sheets.

C2. Composites

When combining information from several data sources into a *composite* it was always possible to bring forth a composite number for failure rates as described in 2.2 of the guide. This was possible because all references provided failure rate information as a minimum. Since not all references contain failures per cycle or outage times, it was not always possible to propagate failures per cycle or outage times. If in Fig C1, level 30.X had outage times whereas 30.a and 30.b did not, then forming an estimate of outage time at the 30-⁴"kluge" level could not be justified.

C3. Round-Off Error

So as to limit the data entries to three digits and four decimal places, round-off errors are given on the data sheets. The sum of the entries under the failure categories of catastrophic, degraded, and incipient often will not add up to the *all modes* failure category at the top of the column. In a similar manner the breakdown of each category into subcategories may not add to the value given for that failure category.

⁴A nondescript item that performs an imaginary function.

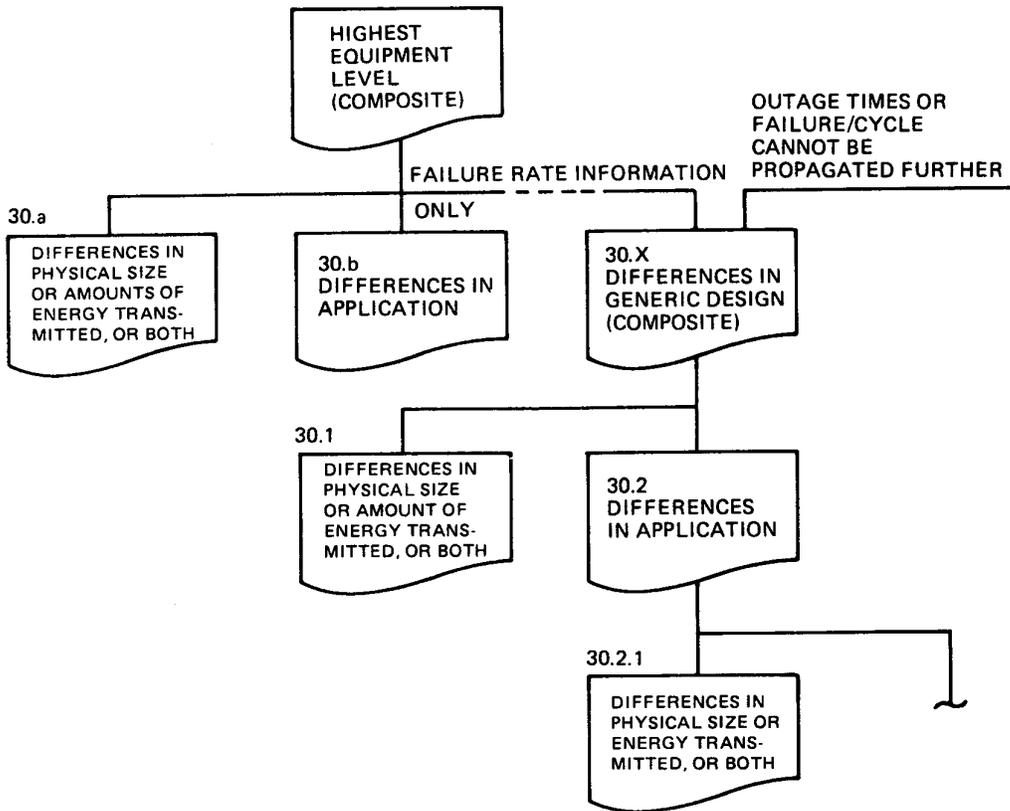


Fig C1
Hypothetical Hierarchical Tree

C4. Notation

So as to have the decimal point fall in the same position in all columns the following format was adopted: 123.1234, or three digits followed by four decimal positions. A number such as 7156, will be entered as 7.16E3. The notation E3 standing for 10 to the third power. There are no negative exponents.

The data under the service columns are shown as "Out of Service (*)", "Repair Time (†)", or "Restore (§)". The data in the columns under these headings, are referenced by (*), (†) and (§), which are always given in the column under the heading LOW, in the fourth decimal place.

For example:

LOW	REC	HIGH
6.25 *	26.4	324.0
†	12.0	
§	18.0	

Appendix D**Reliability Data for Pumps, Actuators, and Valves**

(The data of this Appendix were developed and reviewed by a Subcommittee of the IEEE Nuclear Power Engineering Committee, but have not been reviewed by NPEC or the IEEE Standards Board.)

The current data base does not permit distinction between failure rate estimates in standby and operating modes for all applicable components and all failure modes. When this distinction is not possible the quoted failure-rate estimates must be used and interpreted with care.

References

The sources referenced in Appendix D data pages are as follows:

- [1] ANSI/IEEE Std 500-1977, IEEE Guide to the Collection and Presentation of Electrical, Electronic, and Sensing Component Reliability Data for Nuclear-Power Generating Stations.
- [2] Interim EGG-EA-5B16, April 1982, Data Summaries of Licensee Event Reports of Valves at US Commercial Nuclear Power Plants.
- [3] Corps of Engineers (HND) R/M Data Base, Ground Stationary Equipment, Rep No 16, 04/12/73.
- [4] Nonelectric Parts Reliability Data (NPRD-2) Summer 1981, Reliability Analysis Center, Rome Air Development Center, Griffiss Air Force Base, NY 13441.
- [5] Utility "A"
- [6] Nuclear Unit Productivity Analysis (Special EPRI Report No 46) Aug 1976 (Nonredundant Equipment Only).
- [7] Gas Turbine Manufacturer "A"
- [8] Architectural Engineering Company "A"
- [9] NUREG/CR-1205 Jan 1980, Data Summaries of Licensee Event Reports of Pumps at US Commercial Nuclear Power Plants.
- [10] NUREG/CR-2232, Nuclear Plant Reliability Data System (NPRDS) 1980 Annual Reports of Cumulative System and Component Reliability.
- [11] ANSI/IEEE Std 493-1980, IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems (Gold Book).
- [12] NUREG/CR 2886, May 1982, In-Plant Reliability Data System (IPRDS) Interim Draft Report on the Reliability Characteristics of Selected Pumps in Four Nuclear Plants.
- [13] Pressurized Water Reactor — Plant No 10.
- [14] EPRI Rep No AP 2071, Oct 1981, Component Failure and Repair Data for Coal Fired Power Units.
- [15] R&D Status Report-Advanced Power Systems Division, EPRI Journal, March 1982, p 37.
- [16] Architectural Engineering Company "B".

Chapter 1 Valve Operators and Actuators

Preface

D1.1 Introduction. This chapter contains failure rates, failure modes, and environmental effects which are the basic ingredients necessary for performing an effective reliability analysis on valve operators and actuators.

This information on valves collected from the Delphi questionnaires and IEEE team visits to nine operating power plants contains data on a variety of applications including a balance of nuclear and fossil fuel-plant applications. The team visits to operating plants included at least four engineers from IEEE who were knowledgeable in the field of power applications. They reviewed and copied maintenance records for the previous five-year period and completed lists of the plant installation instruments and operating parts.

D1.2 Hierarchical Tree. Figure D7 is a pictorial representation of the hierarchical structure of Chapter 1 and the procedures in which

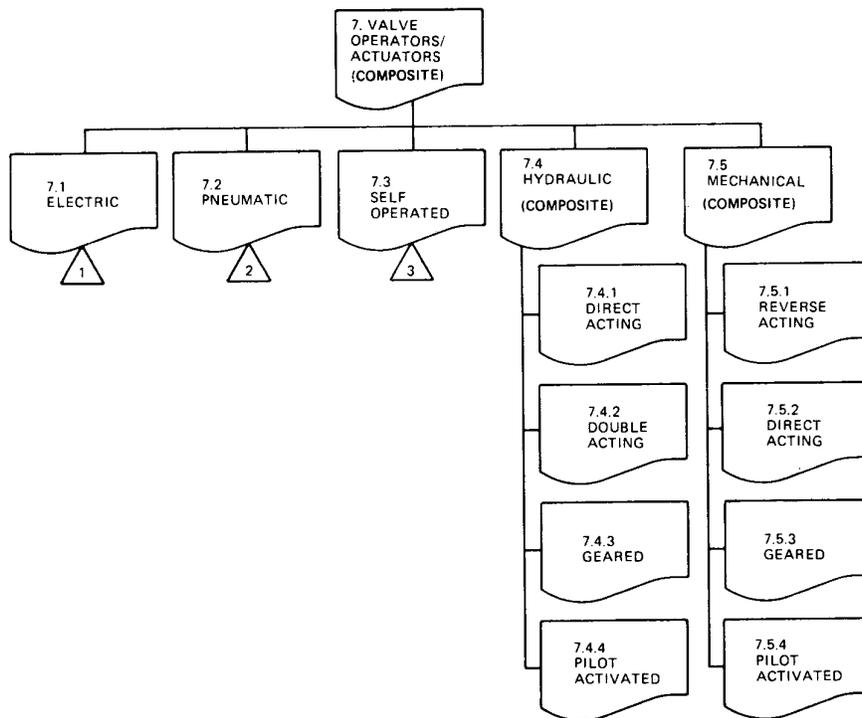
composites were formed for the various levels of information regarding valve operators and actuators, failure rates, and outage times.

If the design calls for a solenoid operated electric, pneumatic, self operated, hydraulic or mechanical operated device, and data are not presently available for so specific a device, the data for the broader drive class may be used to approximate this device, provided that the failure-rate range and the recommended value are considered.

D1.3 The reduced data used in this chapter were taken from the complete failure rate compendium, ANSI/IEEE Std 500-1984. The figures and tables have been reproduced from the same plates and hence carry the designations of Chapter 7 as in the original volume.

Although Chapter 2, Valves, includes the actuators in most cases, this chapter on the actuators is introduced for those whose interest includes the actuator failure rates as separate entities.

Fig D7
Hierarchical Tree
Valve Operators/Actuators



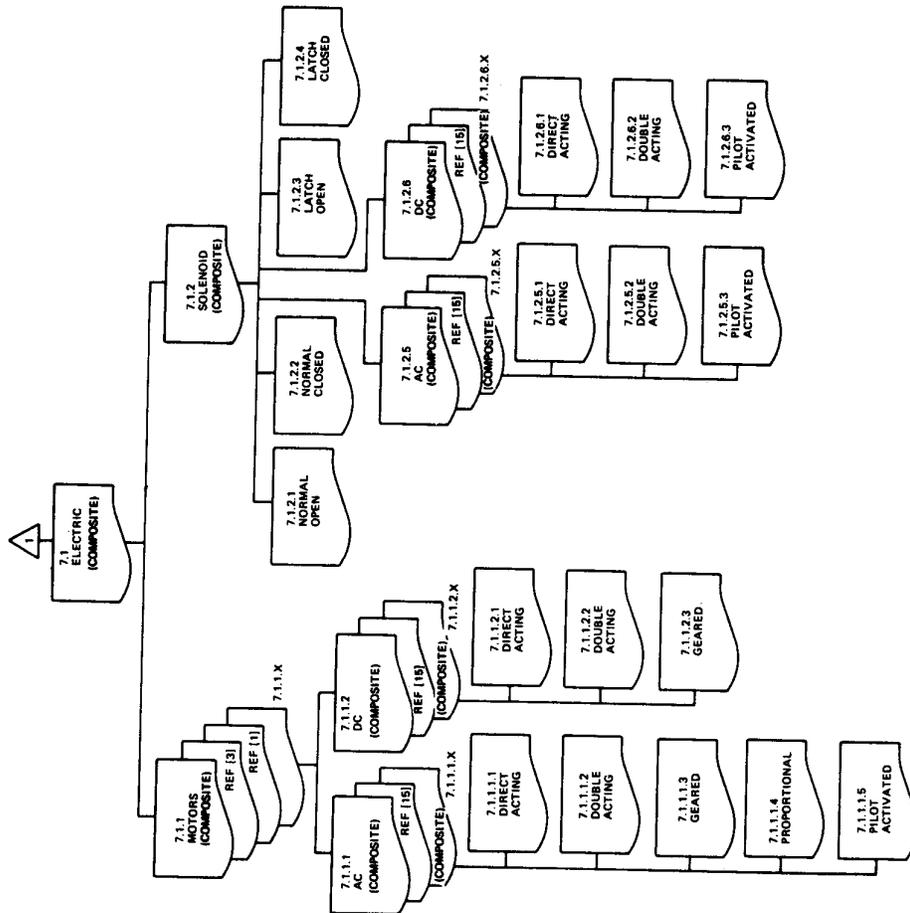


Fig D7 (a)
Valve Operators/Actuators

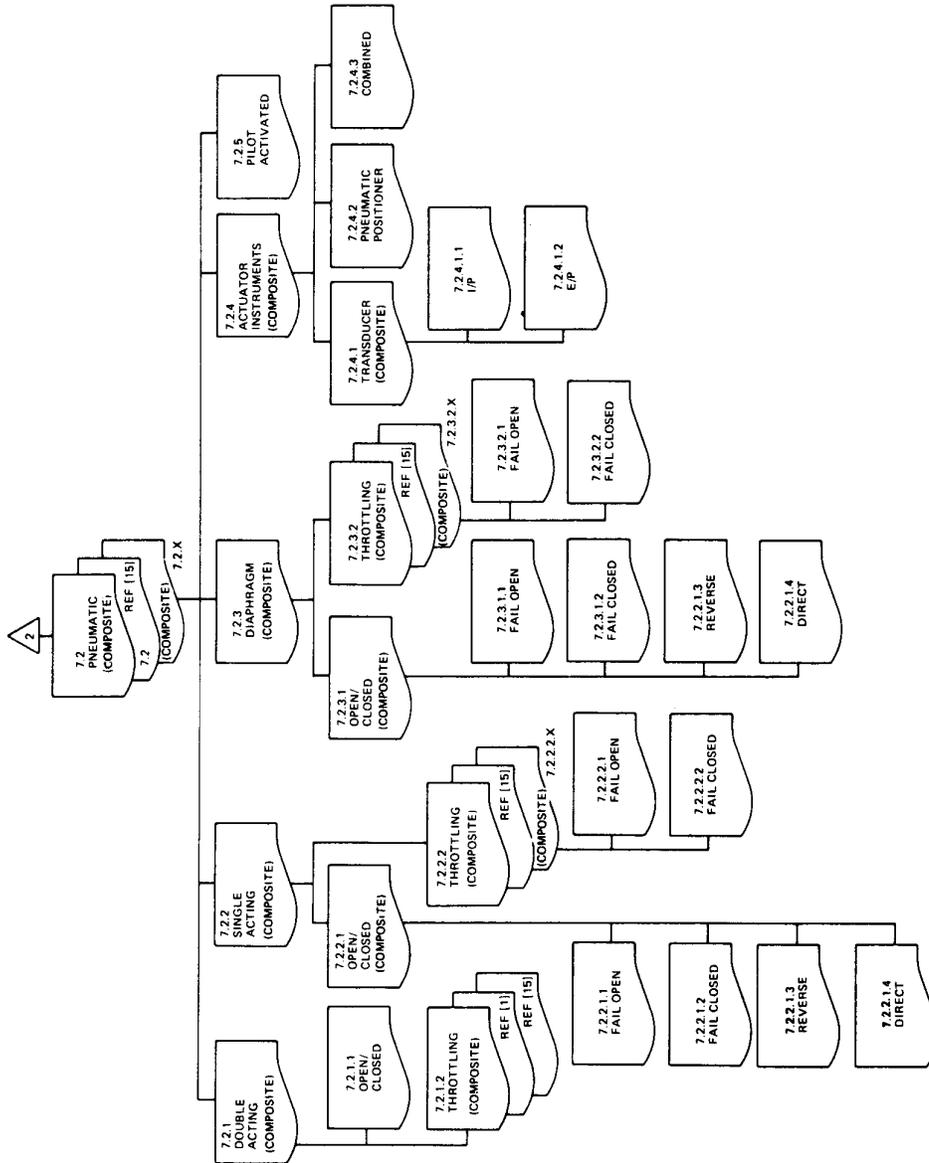


Fig D7 (b)
Valve Operators/Actuators

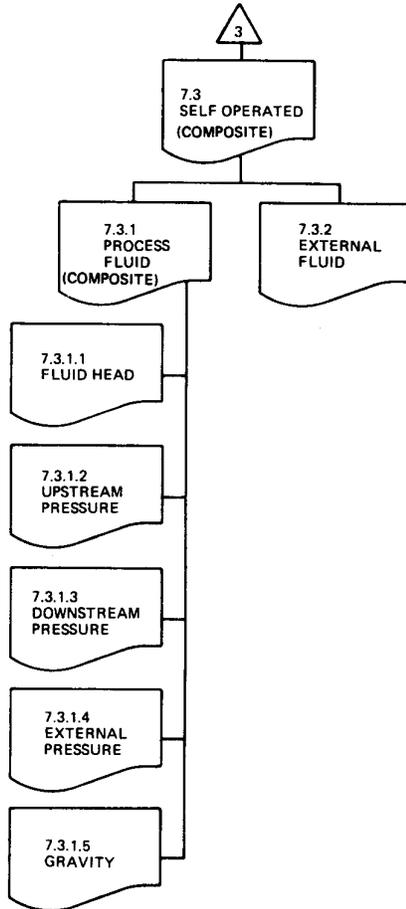


Fig D7 (c)
Valve Operators/Actuators

VALVE ACTUATORS, AND VALVES

D7.3 Failure Modes. The failure modes have been developed on the basis of three mode classes: catastrophic, degraded, and incipient each of which are further developed into subsidiary classes wherever available data permits.

Failure modes are defined in terms of observable effects on the system resulting from some changes in operating characteristic or the state of the device. Thus all failure modes are viewed from the system level rather than the component level.

It must be noted that in Chapter 7 failure modes differ in some cases between the hourly rates and the cyclic rates. Therefore, in these cases, there are two failure modes shown, one for the hourly rate and one for the cyclic rate.

D7.4 Environmental Effects. Such Environmental effects as high temperature, radiation, humidity, and vibration do have an effect on

the failure rates of the valves and valve operators. It is important to point out, however, that a valve is usually required to operate after an incident within a relatively short period of time. This means that the environmental changes as a result of an incident have very little chance to affect valves before they are required to operate. On the other hand, the day-to-day environment may have an effect on valve operation which has been considered in this chapter.

Table D7 gives the environmental factors to be used in conjunction with the failure rates listed. These environmental factors are to be multiplied by the failure rates listed for each particular device under consideration.

D7.5 Data Collection and Analysis Notes

D7.5.1 Operating Practices. It is important to conduct periodic preventive maintenance inspections (for leaks etc). It is also important to

Table D7
Valve Operators and Actuators
Environmental Factor Matrix

Hierarchical Code	High Temperature	High Radiation	High Humidity	High Vibration
7.1	1.57	1.57	2.04	—
7.1.1	1.4	1.1	3.0	—
7.1.2	1.73	2.03	1.07	1.33
7.1.2.1	1.73	2.03	1.07	1.33
7.1.2.2	1.70	2.03	1.07	—
7.1.2.3				
7.1.2.4	1.50	1.55	1.10	2.0
7.2	1.52	1.34	1.24	—
7.2.1	1.67	1.91	1.13	—
7.2.1.1	1.63	2.06	1.03	—
7.2.2	1.54	1.45	1.19	—
7.2.2.1	1.58	1.80	1.18	—
7.2.2.2	1.50	1.10	1.20	—
7.2.3	1.58	1.48	1.18	—
7.2.3.1	1.55	1.55	1.15	—
7.2.3.2	1.60	1.40	1.20	—
7.2.4	1.45	1.10	1.35	—
7.3	1.40	1.10	1.35	—
7.3.1	1.40	1.10	1.35	—
7.3.1.1	1.40	1.10	1.35	—
7.3.1.2	1.40	1.10	1.35	—
7.3.1.3	1.40	1.10	1.35	—
7.3.1.4	1.40	1.10	1.35	—
7.3.1.5	1.35	1.10	1.35	—
7.3.2	1.35	1.10	1.45	—
7.3.2.1	1.35	1.10	1.45	—

periodically replace "O" rings, packing, and seals to counter the effects of radiation, aging, and wear. These maintenance actions should be governed by an established and accepted maintenance plan.

There are many cases of maintenance-induced failures, so care should be exercised to minimize such errors.

D7.5.2 Testing. Periodic surveillance testing is essential to the verification of the reliability of valves, but caution should be used in defining these schedules to ensure that excessive testing does not induce failures. Cases have been reported wherein excessive testing has caused valve failures.

The following listing of failure mode categories occur under the component listings in Chapter 7.

Valve Operators and Actuators Failure Modes Breakdown

All Modes (the sum of catastrophic, degraded and incipient)

Catastrophic

Spurious opening

Spurious closing

Failure to open on demand

Failure to close on demand

Degraded

Premature or delayed actuation (actuation that occurs out of timing sequence)

Partially opening

Partially closing

Incipient

VALVE ACTUATORS, AND VALVES

(Composite of 7.1 through 7.5)
 CHAPTER: 7 Valve Operators & Actuators SECTION: SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE														(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS							FAILURES/10 ⁶ CYCLES **							LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.01	1.73	999.0		0.10	2.27	63.25		1.0 *	35.06	7.28E3							
CATASTROPHIC		0.004	0.69	400.0		0.04	0.91	25.30											
Spurious Opening		0.002	0.34	200.0		0.02	0.45	12.65											
Spurious Closing		0.002	0.35	200.0		0.02	0.46	12.65											
DEGRADED		0.006	1.04	599.0		0.06	1.36	37.95											
Premature or Delayed Actuation		0.006	1.04	599.0															
Partially Opening						0.024	0.54	15.18											
Partially Closing						0.036	0.82	22.77											

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of Ref 1, 3, and 7.1.1.1.X)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.01	0.63	500		0.72	4.87	50.0		1.0 *	41.50	6.49E3					
CATASTROPHIC		0.004	0.25	200.0		0.29	1.95	20.0									
Spurious Opening		0.002	0.13	100.0		0.15	0.98	10.0									
Spurious Closing		0.002	0.12	100.0		0.14	0.97	10.0									
DEGRADED		0.006	0.38	300.0		0.43	2.92	30.0									
Partially Opening						0.17	1.17	12.0									
Partially Closing						0.26	1.75	18.0									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.10	0.62	2.24	1	5.0	10.0	50.0	1								
CATASTROPHIC		0.04	0.25	0.90		2.5	5.0	25.0									
Spurious Opening		0.02	0.13	0.45													
Spurious Closing		0.02	0.12	0.45													
Failure to Open on Demand						1.25	2.50	12.50									
Failure to Close on Demand						1.25	2.50	12.50									
DEGRADED		2.5	5.0	10.00													
Premature or Delayed Actuation		0.06	0.37	1.34													
Partially Opening						1.0	2.0	10.0									
Partially Closing						1.5	3.0	15.0									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Valve Operator Electric Motor (8 Inch Butterfly)	ALL MODES		0.63		3							†	2.0				3

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

(Composite of 7.1.1.1 through 7.1.1.2)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.01	3.91	500.0		0.72	3.75	17.10		1.0 *	41.50	6.49E3					
CATASTROPHIC		0.004	1.56	200.0		0.36	1.88	8.55									
Spurious Opening		0.002	0.78	100.0													
Spurious Closing		0.002	0.78	100.0													
Failure to Open on Demand						0.18	0.94	4.28									
Failure to Close on Demand						0.18	0.94	4.27									
DEGRADED		0.006	2.35	300.0		0.56	1.87	8.55									
Premature or Delayed Actuation		0.006	2.35	300.0		0.22	0.75	3.42									
Partially Opening						0.34	1.12	5.13									
Partially Closing																	

** One Cycle = One Demand

(Composite of Ref 15 and 7.1.1.1.X)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.50	28.2	500.0								1.0 *	41.50	6.49E3		

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
P&V

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.0	62.0	180.0	15							15.0 *	41.0	105.0	15

** One Cycle = One Demand

(Composite of 7.1.1.1.1 through 7.1.1.1.5)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.50	3.16	500.0								1.0 *	96.20	6.49E3			

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC				HIGH	REF
ALL MODES		1.50	14.5	150.0	15								1.0	* 486.0	1.06E3	15

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES		1.30	13.0	130.0	15									*	69.0			15

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.0	2.80	5.0	15									1.0	* 392.0	6.49E3	15

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
7.1.1.1 AC, 7.1.1.1.4 Proportional	ALL MODES	4.0	47.6	476.0	15							*	3.25E3			15

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.50	5.4	500.0	15							* 783.0				15

** One Cycle = One Demand

(Composite of Ref 15 and 7.1.1.1.2.X)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.30	29.60	200.0										1.0 *	160.30	6.49E3	

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		5.0	44.5	200.0	15							3.0 * 168.0	536.0	15	

(Composite of 7.1.1.2.1 through 7.1.1.2.3)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.30	19.60	200.0								1.0 *	90.50	6.49E3			

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
7.1.1.2 DC, 7.1.1.2.1 Direct Acting	ALL MODES	1.45	14.5	200.0	15								1.0 *	486.0	1.05E3	15	

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
7.1.1.2 DC, 7.1.1.2.2 Double Acting	ALL MODES	1.30	13.0	130.0	15							1.0 *	69.0	150.0	15

VALVE ACTUATORS, AND VALVES

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1 Motors

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
7.1.1.2 DC, 7.1.1.2.3 Geared	ALL MODES	5.0	24.2	50.0	15							1.0 *	392.0	6.49E3	15

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.1.2.1 through 7.1.2.6)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.01	0.54	500.0		0.72	3.75	17.10									
CATASTROPHIC		0.004	0.22	200.0		0.36	1.88	8.55									
Spurious Opening		0.002	0.11	100.0													
Spurious Closing		0.002	0.11	100.0													
Failure to open on Demand						0.18	0.94	4.28									
Failure to Close on Demand						0.18	0.94	4.27									
DEGRADED		0.006	0.32	300.0		0.56	1.87	8.55									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.006	0.32	300.0													
Partially Opening						0.22	0.75	3.42									
Partially Closing						0.34	1.12	5.13									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
P&V

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	7.1.2.1 Normally Open	FAILURE RATE													(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
		FAILURE MODE						FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES		0.38	1.04	3.04	1	0.93	3.68	13.6	1														
CATASTROPHIC		0.27	0.75	2.18		0.78	3.09	11.4															
Spurious Opening		0.01	0.04	0.10																			
Spurious Closing		0.26	0.71	2.08																			
Failure to Open on Demand						0.42	1.65	6.07															
Failure to Close on Demand						0.36	1.44	5.33															
DEGRADED		0.11	0.29	0.86		0.15	0.59	2.17															
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)																							
Partially Opening		0.11	0.29	0.86		0.08	0.30	1.09															
Partially Closing						0.07	0.29	1.08															

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.45	1.32	3.84	1	1.26	4.64	17.10	1								
CATASTROPHIC		0.32	0.95	2.75		0.97	3.56	13.11									
Spurious Opening		0.02	0.05	0.13													
Spurious Closing		0.30	0.90	2.62													
Failure to Open on Demand						0.56	2.05	7.55									
Failure to Close on Demand						0.41	1.51	5.56									
DEGRADED		0.13	0.37	1.09		0.29	1.08	3.99									
Premature or Delayed Actuation (Actuation that occurs out of sequence)		0.13	0.37	1.09													
Partially Opening						0.20	0.74	2.71									
Partially Closing						0.09	0.34	1.28									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
P&V

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.14	0.40	1.27	1	0.71	3.46	14.14	1								
CATASTROPHIC		0.13	0.38	1.21		0.55	2.68	10.96									
Spurious Opening		0.04	0.12	0.38													
Spurious Closing		0.09	0.26	0.83													
Failure to Open on Demand						0.34	1.64	6.72									
Failure to Close on Demand						0.21	1.04	4.24									
DEGRADED		0.007	0.02	0.087		0.16	0.78	3.18									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.007	0.02	0.087													
Partially Opening						0.08	0.39	1.59									
Partially Closing						0.08	0.39	1.59									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.14	0.40	1.27	1	0.71	3.46	14.14	1								
CATASTROPHIC		0.13	0.38	1.21		0.55	2.68	10.96									
Spurious Opening		0.04	0.12	0.38													
Spurious Closing		0.09	0.26	0.83													
Failure to Open on Demand						0.34	1.64	6.72									
Failure to Close on Demand						0.21	1.04	4.24									
DEGRADED		0.007	0.02	0.064		0.16	0.78	3.18									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.007	0.02	0.064													
Partially Opening						0.08	0.39	1.59									
Partially Closing						0.08	0.39	1.59									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

(Composite of Ref 15 and 7.1.2.5.X)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.01	2.14	500.0									7.0 *	40.8	600.0		

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.52	15.2	500.0	15							*	22.0				15

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
P&V

(Composite of 7.1.2.5.1 through 7.1.2.5.3)

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.01	0.30	500.0									*	75.8	600.0		

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
7.1.2.5 AC, 7.1.2.5.1 Direct Acting	ALL MODES	0.13	1.27	500.0	15							*	122.0				15

VALVE ACTUATORS, AND VALVES

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
7.1.2.5 AC, 7.1.2.5.2 Double Acting	ALL MODES	0.09	0.93	300.0	15									7.0 *	8.0	11.0	15

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
7.1.2.5 AC, 7.1.2.5.3 Pilot Activated	ALL MODES	0.01	0.08	200.0	15							*	4.22E3			15

VALVE ACTUATORS, AND VALVES

(Composite of Ref 15 and 7.1.1.2.6.X)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.01	3.51	500								2.0 *	66.40	8.03E3	

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
7.1.2.6 DC	ALL MODES	1.50	3.05	200.0	15							7.0 *	65.0	216.0	15

(Composite of 7.1.2.6.1 through 7.1.2.6.3)

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.1 Electric

SUBSECTION: 7.1.2 Solenoid

VALVE ACTUATORS, AND VALVES

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (1) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.01	5.01	500.0								2.0	*152.0	8.03E3			

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
7.1.2.6 DC, 7.1.2.6.1 Direct Acting	ALL MODES	2.50	4.76	47.60	15							2.0	* 701.0	8.03E3	15

VALVE ACTUATORS, AND VALVES

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.1 Electric SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
7.1.2.6 DC, 7.1.2.6.2 Double Acting	ALL MODES	0.01	6.21	500.0	15								20.0 *	80.0	600.0	15	

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.2 Electric

SUBSECTION: 7.1.2 Solenoid

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
7.1.2.6. DC, 7.1.2.6.3 Pilot Activated	ALL MODES	0.58	5.77	200.0	15							9.0 *	29.0	45.0	15

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
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(Composite of Ref 15 and 7.2.X)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.03	0.89	999.0		0.10	1.62	63.25									
CATASTROPHIC		0.025	0.75	837		0.06	0.97	37.95									
Spurious Opening		0.013	0.38	419													
Spurious Closing		0.012	0.37	418													
Failure to Open on Demand						0.029	0.47	18.37									
Failure to Close on Demand						0.031	0.50	19.62									
DEGRADED		0.005	0.14	162.0		0.04	0.65	25.30									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.005	0.14	162.0													
Partially Opening						0.02	0.32	12.65									
Partially Closing						0.02	0.33	12.65									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		5.0	508.0	999.0	15							2.0 *	148.0	1.59E3	15

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
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(Composite of 7.2.1 through 7.2.5)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.03	0.47	100.0		0.10	1.62	63.25									
CATASTROPHIC		0.025	0.39	83.8		0.06	0.97	37.95									
Spurious Opening		0.013	0.20	41.9													
Spurious Closing		0.012	0.19	41.9													
Failure to Open on Demand						0.029	0.47	18.33									
Failure to Close on Demand						0.031	0.50	19.62									
DEGRADED		0.005	0.08	16.2		0.04	0.65	25.30									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.005	0.08	16.2													
Partially Opening						0.02	0.32	12.65									
Partially Closing						0.02	0.33	12.65									

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.2.1.1 through 7.2.1.2)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.1 Double Acting Piston Actuator

FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
	FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF	
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
ALL MODES	0.34	1.27	27.50		0.63	3.98	48.26		0.20	1.26	15.30						
CATASTROPHIC	0.28	1.06	22.91		0.43	2.72	32.96										
Spurious Opening	0.14	0.53	11.45														
Spurious Closing	0.14	0.53	11.46														
DEGRADED	0.06	0.21	1.27														
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)	0.06	0.21	1.27														
Partially Opening					0.10	0.63	7.65										
Partially Closing					0.10	0.63	7.65										

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
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ITEM OR EQUIPMENT DESCRIPTION		FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
			FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF	
			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
(Composite of Ref 1 and 15)																			
CHAPTER: 7	Valve Operators & Actuators	SECTION: 7.2	Pneumatic	SUBSECTION: 7.2.1	Double Acting Piston Actuator														
7.2.1.2 Throttling Composite																			
	ALL MODES		0.77	2.89	27.50			2.97	9.36	49.26									
	CATASTROPHIC		0.56	2.12	20.16			1.58	4.99	25.74									
	Spurious Opening		0.56	2.12	20.16														
	Failure to Open on Demand							0.79	2.50	12.87									
	Failure to Close on Demand							0.79	2.50	12.87									
	DEGRADED		0.21	0.77	7.34			1.38	4.37	22.52									
	Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.21	0.77	7.34														
	Partially Opening							0.69	2.19	11.26									
	Partially Closing							0.69	2.18	11.26									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.1 Double Acting Piston Actuator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
7.2.1.2 Throttling	ALL MODES	1.51	3.51	80.0	15							1.0	* 405.0	4.02E3	15

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)			
		FAILURE MODE						FAILURE RATE						LOW	REC	HIGH	REF
		FAILURE MODE			FAILURE RATE			FAILURE MODE			FAILURE RATE						
LOW	REC	HIGH	LOW	REC	HIGH	LOW	REC	HIGH	LOW	REC	HIGH	LOW	REC	HIGH	REF		
ALL MODES		0.77	2.71	27.50	1	1	2.97	9.36	48.26	1							
CATASTROPHIC		0.58	1.99	20.17			1.58	4.99	25.74								
Spurious Opening		0.58	1.99	20.17													
Failure to Open on Demand							0.79	2.50	12.87								
Failure to Close on Demand							0.79	2.50	12.87								
DEGRADED		0.19	0.72	7.33			1.39	4.37	22.52								
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.19	0.72	7.33													
Partially Opening							0.69	2.18	11.26								
Partially Closing							0.70	2.19	11.26								

** One Cycle = One Demand

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURE MODE						FAILURE RATE						LOW	REC	HIGH	REF
		FAILURE MODE			FAILURE RATE			FAILURE MODE			FAILURE RATE						
LOW	REC	HIGH	LOW	REC	HIGH	LOW	REC	HIGH	LOW	REC	HIGH	LOW	REC	HIGH	REF		
ALL MODES		0.34	1.09	5.44	1	0.63	2.92	17.10	1								
CATASTROPHIC		0.28	0.90	4.53		0.43	2.0	11.68									
Spurious Opening		0.14	0.45	2.27													
Spurious Closing		0.14	0.45	2.26													
Failure to Open on Demand						0.19	0.88	5.13									
Failure to Close on Demand						0.24	1.12	6.55									
DEGRADED		0.057	0.19	0.91		0.20	0.92	5.42									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.057	0.19	0.91													
Partially Opening						0.10	0.46	2.71									
Partially Closing						0.10	0.46	2.71									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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(Compositional ... through 7.2.2.2)
CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.25	1.44	15.0		0.71	4.77	63.25									
CATASTROPHIC		0.23	1.30	13.50		0.49	3.29	43.64									
Spurious Opening		0.11	0.62	6.37													
Spurious Closing		0.12	0.68	7.13													
Failure to Open on Demand						0.22	1.45	19.20									
Failure to Close on Demand						0.27	1.84	24.44									
DEGRADED		0.02	0.14	1.50		0.22	1.48	19.61									
Premature or Delayed Actuation (Actuation occurs out of timing sequence)		0.02	0.14	1.50		0.10	1.68	9.02									
Partially Opening						0.12	0.80	10.59									
Partially Closing																	

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.2.2.1.1 through 7.2.2.1.4)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.2 Single Acting
Piston Actuator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.25	1.12	9.50		0.71	4.16	22.36									
CATASTROPHIC		0.23	1.01	8.55		0.49	2.86	15.38									
Spurious Opening		0.11	0.48	4.04													
Spurious Closing		0.12	0.53	4.51													
Failure to Open on Demand						0.21	1.25	6.71									
Failure to Close on Demand						0.28	1.61	8.67									
DEGRADED		0.02	0.11	0.95		0.22	1.30	6.99									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.02	0.11	0.95													
Partially Opening						0.10	0.60	3.22									
Partially Closing						0.12	0.70	3.77									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURE RATES/10 ⁶ HOURS						FAILURE RATES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.2 Single Acting Piston Activator																
7.2.2.1 Open/Closed Service, 7.2.2.1.1 Fail Open																		
ALL MODES		0.25	0.75	2.30	1	0.71	4.16	22.36										
CATASTROPHIC		0.23	0.68	2.07		0.49	2.86	15.38										
Spurious Opening		0.11	0.32	0.98														
Spurious Closing		0.12	0.36	1.09														
Failure to Open on Demand						0.21	1.25	6.71										
Failure to Close on Demand						0.28	1.61	8.67										
DEGRADED		0.025	0.075	0.23		0.22	1.30	6.99										
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.025	0.075	0.23														
Partially Opening						0.10	0.60	3.22										
Partially Closing						0.12	0.70	3.77										

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.2 Single Acting Piston Actuator	FAILURE MODE		FAILURE RATE														
			ITEM OR EQUIPMENT DESCRIPTION	7.2.2.1 Open/Closed Service, 7.2.2.1.2	FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
					0.25	0.75	2.30	1	0.71	4.16	22.36	1	0.23	0.075	0.23	0.10	0.60	3.22	
ALL MODES	0.23	0.68	2.07		0.49	2.86	15.38												
CATASTROPHIC	0.11	0.32	0.98																
Spurious Opening	0.12	0.36	1.09																
Spurious Closing					0.21	1.25	6.71												
Failure to Open on Demand					0.28	1.61	8.67												
Failure to Close on Demand					0.23	1.30	6.99												
DEGRADED	0.025	0.075	0.23																
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)	0.025	0.075	0.23																
Partially Opening					0.12	0.70	3.77												
Partially Closing																			

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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CHAPTER: 7 Valve Operators & Actuators		SECTION: 7.2 Pneumatic		SUBSECTION: 7.2.2 Single Acting Piston Actuator									
ITEM OR EQUIPMENT DESCRIPTION		7.2.2.1 Open/Closed Service, 7.2.2.1.3 Reverse											
FAILURE MODE	FAILURE RATE	FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				(*) OUT OF SERVICE TIME OR (\$) RESTORE (HOURS)			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
		ALL MODES	1.50	3.46	9.50	15					0	* 425.0	5.E3

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.2 Single Acting Piston Actuator	ITEM OR EQUIPMENT DESCRIPTION 7.2.2.1 Open/Closed Service, 7.2.2.1.4 Direct Acting	FAILURE RATE														
				FAILURE MODE			FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES			(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH
			ALL MODES	2.50	4.85	8.50	15							0	* 256.0	3.42E3	15	

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
P&V

(Composite of Ref 15 and 7.2.2.2.X)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.2 Single Acting Piston Actuator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.45	2.14	15.0		1.44	7.07	63.25									
CATASTROPHIC		0.25	1.18	8.25		0.56	2.83	25.30									
Spurious Opening		0.13	0.59	4.13													
Spurious Closing		0.12	0.59	4.12													
Failure to Open on Demand						0.28	1.41	12.60									
Failure to Close on Demand						0.28	1.42	12.70									
DEGRADED		0.20	0.96	6.75		0.85	4.24	37.95									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.20	0.96	6.75		0.42	2.12	18.97									
Partially Opening						0.42	2.12	18.97									
Partially Closing						0.42	2.12	18.98									

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.2 Single Acting Piston Actuator	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE														
					FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
																	LOW	HIGH	REF
			ALL MODES	1.50	3.51	50.0	15							1.0	* 405.0	4.02E3	15		

VALVE ACTUATORS, AND VALVES

ANSI/IEEE
Std 500-1984
P&V

(Composite of 7.2.2.2.1 through 7.2.2.2.2)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.2 Single Acting
Piston Actuator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.45	2.0	7.07		1.44	7.07										
CATASTROPHIC		0.25	1.10	3.90		0.56	2.83										
Spurious Opening		0.12	0.55	1.95													
Spurious Closing		0.13	0.55	1.95													
Failure to Open on Demand						0.28	1.41										
Failure to Close on Demand						0.28	1.42										
DEGRADED		0.20	0.90	3.18		0.85	4.24										
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.20	0.90	3.18													
Partially Opening						0.42	2.12										
Partially Closing						0.43	2.12										

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.2 Single Acting Piston Actuator	ITEM OR EQUIPMENT DESCRIPTION 7.2.2.2 Throttling, 7.2.2.2.1 Failed Open	FAILURE RATE															
				FAILURE MODE				FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES **				(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES	0.45	2.0	7.07	1	1.41	7.07	63.25	1	0.28	1.41	12.65								
CATASTROPHIC	0.25	1.10	3.90		0.56	2.83	25.30		0.28	1.42	12.65								
Spurious Opening	0.12	0.55	1.95						0.85	4.24	37.85								
Spurious Closing	0.13	0.55	1.95																
Failure to Open on Demand																			
Failure to Close on Demand																			
DEGRADED	0.20	0.90	3.18		0.42	2.12	18.92		0.43	2.12	18.93								
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)	0.20	0.90	3.18																
Partially Opening																			
Partially Closing																			

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.45	2.0	7.07	1	1.41	7.07	63.25	1								
CATASTROPHIC		0.25	1.10	3.90		0.56	2.83	25.30									
Spurious Opening		0.12	0.55	1.95													
Spurious Closing		0.13	0.55	1.95													
Failure to Open on Demand						0.28	1.41	12.65									
Failure to Close on Demand						0.28	1.42	12.65									
DEGRADED		0.20	0.90	3.18		0.85	4.24	37.5									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.20	0.90	3.18													
Partially Opening						0.42	2.12	18.92									
Partially Closing						0.43	2.12	18.93									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.2 Single Acting Piston Actuator

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.2.3.1 through 7.2.3.2)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.3 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.07	0.42	1.00		0.28	1.34	4.93		0.07	0.34	1.26					
CATASTROPHIC		0.06	0.36	86.40		0.14	0.68	2.52		0.07	0.34	1.26					
Spurious Opening		0.03	0.18	43.20						0.07	0.34	1.26					
Spurious Closing		0.03	0.18	43.20						0.14	0.66	2.41					
Failure to Open on Demand																	
Failure to Close on Demand																	
DEGRADED		0.01	0.06	13.6						0.07	0.33	1.20					
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)										0.07	0.33	1.21					
Partially Opening		0.01	0.06	13.6													
Partially Closing																	

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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(Composite of 7.2.3.1.1 through 7.2.3.1.4)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.3 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.10	0.49	35.0		0.28	1.19	3.76									
CATASTROPHIC		0.093	0.45	32.39		0.14	0.58	1.83									
Spurious Opening		0.05	0.23	16.48													
Spurious Closing		0.043	0.22	15.91													
Failure to Open on Demand						0.06	0.25	0.80									
Failure to Close on Demand						0.08	0.33	1.03									
DEGRADED		0.007	0.04	2.61		0.14	0.61	1.93									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.007	0.04	2.61													
Partially Opening						0.072	0.31	0.96									
Partially Closing						0.072	0.31	0.96									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.3 Diaphragm Spring Opposed	ITEM OR EQUIPMENT DESCRIPTION 7.2.3.1 Open/Closed Service, 7.2.3.1.1 Fails Open	FAILURE RATE														
				FAILURE MODE				FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES **				(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH
ALL MODES	0.10	0.36	1.78	1	0.28	1.19	3.76	1										
CATASTROPHIC	0.093	0.33	1.64		0.14	0.58	1.83											
Spurious Opening	0.048	0.17	0.85															
Spurious Closing	0.045	0.16	0.79		0.06	0.25	0.80											
Failure to Open on Demand					0.08	0.33	1.03											
Failure to Close on Demand	0.008	0.029	0.14		0.14	0.61	1.93											
DEGRADED																		
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)	0.008	0.029	0.14		0.072	0.31	0.96											
Partially Opening					0.072	0.31	0.96											
Partially Closing					0.072	0.31	0.96											

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.3 Diaphragm Spring Opposed

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.10	0.36	1.78	1	0.28	1.19	3.76	1								
CATASTROPHIC		0.093	0.33	1.64		0.14	0.58	1.83									
Spurious Opening		0.048	0.17	0.85													
Spurious Closing		0.045	0.16	0.79													
Failure to Open on Demand						0.06	0.25	0.80									
Failure to Close on Demand						0.08	0.33	1.03									
DEGRADED		0.008	0.029	0.14		0.14	0.61	1.93									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.008	0.029	0.14													
Partially Opening						0.072	0.31	0.96									
Partially Closing						0.072	0.31	0.96									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.3 Diaphragm	ITEM OR EQUIPMENT DESCRIPTION 7.2.3.1 Open/Closed Service, 7.2.3.1.3 Reverse Acting	FAILURE RATE														
				FAILURE MODE					FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
				FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
ALL MODES	1.0	3.46	35.0	15										0	* 425.0	5.£3	15	

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.2.3.2.X and Ref 15)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.3 Diaphragm Spring
Opposed

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.07	0.28	100.0		0.32	1.58	4.93									
CATASTROPHIC		0.056	0.22	50.0		0.17	0.84	2.63									
Spurious Opening		0.028	0.11	25.0													
Spurious Closing		0.028	0.11	25.0													
Failure to Open on Demand						0.08	0.42	1.31									
Failure to Close on Demand						0.09	0.42	1.32									
DEGRADED		0.014	0.056	20.0		0.15	0.74	2.30									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.014	0.056	20.0													
Partially Opening						0.08	0.37	1.15									
Partially Closing						0.07	0.37	1.15									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.3 Diaphragm Spring Opposed

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.50	3.51	100.0	15									1.0	* 405.0	4.02E3	15
CATASTROPHIC		1.20	2.81	80.0													
Spurious Opening		0.60	1.40	40.0													
Spurious Closing		0.60	1.41	40.0													
DEGRADED		0.30	0.70	20.0													
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.30	0.70	20.0													

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.2.3.2.1 through 7.2.3.2.2)

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.3 Diaphragm Spring Opposed

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.07	0.27	1.59		0.32	1.58	4.93									
CATASTROPHIC		0.056	0.22	1.27		0.17	0.84	2.63									
Spurious Opening		0.028	0.11	0.63													
Spurious Closing		0.028	0.11	0.64													
Failure to Open on Demand						0.08	0.42	1.31									
Failure to Close on Demand						0.09	0.42	1.32									
DEGRADED		0.014	0.054	0.32		0.15	0.74	2.30									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.014	0.054	0.32													
Partially Opening						0.08	0.37	1.10									
Partially Closing						0.07	0.37	1.20									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.07	0.27	1.59	1	0.32	1.58	4.93	1								
CATASTROPHIC		0.056	0.22	1.27		0.17	0.84	2.63									
Spurious Opening		0.028	0.11	0.63													
Spurious Closing		0.028	0.11	0.64													
Failure to Open on Demand						0.08	0.42	1.31									
Failure to Close on Demand						0.09	0.42	1.32									
DEGRADED		0.014	0.054	0.32		0.15	0.74	2.30									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.014	0.054	0.32		0.08	0.37	1.15									
Partially Opening						0.07	0.37	1.15									
Partially Closing																	

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.3 Diaphragm Spring Opposed

ITEM OR EQUIPMENT DESCRIPTION: 7.2.3.2 Throttling, 7.2.3.2.1 Fail Open

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.3 Diaphragm Spring Opposed																
7.2.3.2 Throttling	7.2.3.2.2 Fail Closed																	
ALL MODES		0.07	0.27	1.59	1	0.32	1.58	4.93	1									
CATASTROPHIC		0.056	0.22	1.27		0.17	0.84	2.63										
Spurious Opening		0.028	0.11	0.63														
Spurious Closing		0.028	0.11	0.64														
Failure to Open on Demand						0.08	0.42	1.31										
Failure to Close on Demand						0.09	0.42	1.32										
DEGRADED		0.014	0.054	0.32		0.15	0.74	2.30										
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.014	0.054	0.32		0.08	0.37	1.15										
Partially Opening						0.07	0.37	1.15										
Partially Closing																		

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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(Composite of 7.2.4.1 through 7.2.4.3)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.4 Actuator
Instruments

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.03	0.28	3.87		0.10	1.73	15.81		0.03	0.52	4.74					
CATASTROPHIC		0.023	0.21	2.90		0.06	1.04	9.49		0.03	0.52	4.75					
Spurious Opening		0.011	0.10	1.45													
Spurious Closing		0.012	0.12	1.45													
Failure to Open on Demand																	
Failure to Close on Demand																	
DEGRADED		0.008	0.07	0.97		0.04	0.69	6.32		0.02	0.34	3.16					
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.008	0.07	0.97						0.02	0.35	3.16					
Partially Opening																	
Partially Closing																	

** One Cycle = One Demand

(Composite of 7.2.4.1.1 through 7.2.4.1.2)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.2 Pneumatic

SUBSECTION: 7.2.4 Actuator
Instruments

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.03	0.28	3.87		0.10	1.73	15.81									
CATASTROPHIC		0.023	0.21	2.90		0.06	1.04	9.49									
Spurious Opening		0.011	0.10	1.45													
Spurious Closing		0.012	0.12	1.45													
Failure to Open on Demand						0.03	0.52	4.25									
Failure to Close on Demand						0.03	0.52	4.24									
DEGRADED		0.008	0.07	0.97		0.04	0.69	6.32									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.008	0.07	0.97													
Partially Opening						0.02	0.34	3.16									
Partially Closing						0.02	0.34	3.16									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.4 Actuator Instruments																
7.2.4.1 Transducer, 7.2.4.1.1 I/P																		
ALL MODES		0.03	0.28	3.87	1	0.10	1.75	15.81	1									
CATASTROPHIC		0.023	0.21	2.90		0.06	1.04	9.49										
Spurious Opening		0.011	0.10	1.45														
Spurious Closing		0.012	0.11	1.45														
Failure to Open on Demand						0.03	0.52	4.24										
Failure to Close on Demand						0.03	0.52	4.25										
DEGRADED		0.008	0.07	0.97		0.04	0.69	6.32										
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.008	0.07	0.97														
Partially Opening						0.02	0.34	3.16										
Partially Closing						0.02	0.35	3.16										

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.4 Actuator Instruments	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURE MODE						FAILURE RATE						LOW	REC	HIGH	REF
					FAILURES/10 ⁶ HOURS			FAILURES/10 ⁶ CYCLES **			LOW	REC	HIGH	REF						
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH					REF	LOW	REC	HIGH	REF	
			7.2.4.1 Transducer, 7.2.4.1.2 Electro-Pneumatic		0.03	0.28	3.87	1	0.10	1.73	15.81	1								
			ALL MODES		0.023	0.21	2.90		0.06	1.04	9.49									
			CATASTROPHIC		0.011	0.11	1.45													
			Spurious Opening		0.012	0.12	1.45		0.03	0.52	4.24									
			Spurious Closing						0.03	0.52	4.25									
			Failure to Open on Demand						0.04	0.69	6.32									
			Failure to Close on Demand		0.008	0.07	0.97													
			DEGRADED		0.008	0.07	0.97		0.02	0.34	3.16									
			Premature or Delayed Actuation (Actuation that occurs out of timing sequence)						0.02	0.35	3.16									
			Partially Opening																	
			Partially Closing																	

** One Cycle = One Demand

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.4 Actuator Instruments

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.03	0.28	3.87	1	0.10	1.75	15.81	1								
CATASTROPHIC		0.023	0.21	2.90		0.06	1.04	9.49									
Spurious Opening		0.012	0.10	1.45													
Spurious Closing		0.011	0.12	1.45													
Failure to Open on Demand						0.03	0.52	4.24									
Failure to Close on Demand						0.03	0.52	4.25									
DEGRADED		0.008	0.07	0.97		0.04	0.69	6.32									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.008	0.07	0.97													
Partially Opening						0.02	0.34	3.16									
Partially Closing						0.02	0.35	3.16									

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.2 Pneumatic	SUBSECTION: 7.2.4 Actuator Instruments	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
			ALL MODES		0.03	0.28	3.87	1	0.10	1.73	15.81	1								
			CATASTROPHIC		0.023	0.21	2.90		0.06	1.04	9.49									
			Spurious Opening		0.011	0.10	1.45													
			Spurious Closing		0.012	0.11	1.45													
			Failure to Open on Demand						0.03	0.52	4.24									
			Failure to Close on Demand						0.03	0.52	4.25									
			DEGRADED		0.008	0.07	0.97		0.04	0.69	6.32									
			Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.008	0.07	0.97													
			Partially Opening						0.02	0.34	3.16									
			Partially Closing						0.02	0.35	3.16									

** One Cycle = One Demand

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.2 Pneumatic SUBSECTION: 7.2.4 Actuator Instruments

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		2.0	4.05	100.0	15												

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 7.3.1 through 7.3.2)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.3 Self Operated

SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.07	1.26	5.48		0.50	1.91	17.32									
CATASTROPHIC		0.049	0.88	3.84		0.35	1.34	12.12									
Spurious Position Change		0.049	0.88	3.84													
Failure to Change Position on Demand		0.021	0.38	1.64		0.35	1.34	12.12									
DEGRADED		0.021	0.38	1.64		0.15	0.57	5.20									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)																	
Partial Position Change		0.021	0.38	1.64		0.15	0.57	5.20									

** One Cycle = One Demand

VALVE ACTUATORS, AND VALVES

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
	ALL MODES	0.07	0.63	1.73		0.50	1.40	5.48									
	CATASTROPHIC	0.049	0.44	1.21		0.23	0.63	2.47									
	Spurious Position Change	0.049	0.44	1.21													
	Failure to Change Position on Demand					0.23	0.63	2.47									
	DEGRADED	0.021	0.19	0.52		0.28	0.77	3.01									
	Premature or Delayed Actuation (Actuation that occurs out of timing sequence)																
	Partial Position Change	0.021	0.19	0.52		0.28	0.77	3.01									

** One Cycle = One Demand

COMPOSITE OF 7.3.1.1 THROUGH 7.3.1.3

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.3 Self Operated

SUBSECTION: 7.3.1 Process Fluid Actuators

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.3 Self Operated	SUBSECTION: 7.3.1 Process Fluid Actuators	ITEM OR EQUIPMENT DESCRIPTION 7.3.1.1 Fluid Head	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
				FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES				0.07	0.63	1.73	1	0.50	1.40	5.48	1								
CATASTROPHIC				0.049	0.44	1.20		0.23	0.63	2.47									
Spurious Position Change				0.049	0.44	1.20													
Failure to Change Position on Demand								0.23	0.63	2.47									
DEGRADED				0.021	0.19	0.52		0.28	0.77	3.01									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)				0.021	0.19	0.52													
Partial Position Change								0.28	0.77	3.01									

** One Cycle = One Demand

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.3 Self Operated	SUBSECTION: 7.3.1 Process Fluid Actuators															
7.3.1.2 Upstream Pressure		0.07	0.63	1.73	1	0.50	1.40	5.48	1								
CATASTROPHIC		0.049	0.44	1.21		0.23	0.63	2.47									
Spurious Position Change		0.049	0.44	1.21													
Failure to Change Position on Demand						0.23	0.63	2.47									
DEGRADED		0.021	0.19	0.52		0.28	0.77	3.01									
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)																	
Partial Position Change		0.021	0.19	0.52		0.28	0.77	3.01									

** One Cycle = One Demand

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.3 Self Operated	SUBSECTION: 7.3.1 Process Fluid Actuators	FAILURE RATE		FAILURE RATE			FAILURE RATE				
			FAILURES/10 ⁶ HOURS			FAILURES/10 ⁶ CYCLES **			(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
			LOW	REC	HIGH	REF	LOW	REC	HIGH	LOW	REC	HIGH
ALL MODES	0.07	0.63	1.73	1	0.50	1.40	5.48					
CATASTROPHIC	0.049	0.44	1.21		0.23	0.63	2.47					
Spurious Position Change	0.049	0.44	1.21									
Failure to Change Position on Demand					0.23	0.63	2.47					
DEGRADED	0.021	0.19	0.52		0.28	0.77	3.01					
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)												
Partial Position Change	0.021	0.19	0.52		0.28	0.77	3.01					

** One Cycle = One Demand

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.3 Self Operated	SUBSECTION: 7.3.1 Process Fluid Actuators													
7.3.1.4 External Pressure		0.07	0.63	1.73	1	0.50	1.41	5.48	1						
ALL MODES		0.049	0.44	1.21		0.23	0.63	2.47							
CATASTROPHIC		0.049	0.44	1.21		0.23	0.63	2.47							
Spurious Position Change															
Failure to Change Position on Demand															
DEGRADED		0.021	0.19	0.52		0.28	0.77	3.01							
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.021	0.19	0.52		0.28	0.77	3.01							
Partial Position Change															

** One Cycle = One Demand

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 7 Valve Operators & Actuators ITEM OR EQUIPMENT DESCRIPTION	SECTION: 7.3 Self Operated SUBSECTION: 7.3.1 Process Fluid Actuators	FAILURE MODE	FAILURE RATE														
			FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES **						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES CATASTROPHIC Spurious Position Change Failure to Change Position on Demand			0.07	0.63	1.73	1	0.50	1.40	5.48								
			0.049	0.44	1.21		0.23	0.63	2.47								
			0.049	0.44	1.21												
			0.021	0.19	0.52		0.23	0.63	2.47								
DEGRADED Premature or Delayed Actuation (Actuation that occurs out of timing sequence) Partial Position Change			0.021	0.19	0.52		0.28	0.77	3.01								
						0.28	0.77	3.01									

** One Cycle = One Demand

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES **					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.3 Self Operated	SUBSECTION: 7.3.2 External Fluid Actuators																
7.3.2.1 Temp Regulator, Filled System Thermal Bulb																		
ALL MODES		0.07	2.0	5.48	1	0.50	5.48	17.32	1	0.20	5.48	17.32						
CATASTROPHIC		0.046	1.30	3.56		0.20	2.19	6.93		0.30	2.19	6.93						
Spurious Position Change		0.046	1.30	3.56		0.20	2.19	6.93		0.30	2.19	6.93						
Failure to Change Position on Demand		0.024	0.70	1.92		0.30	3.29	10.39		0.30	3.29	10.39						
DEGRADED		0.024	0.70	1.92		0.30	3.29	10.39		0.30	3.29	10.39						
Premature or Delayed Actuation (Actuation that occurs out of timing sequence)		0.024	0.70	1.92		0.30	3.29	10.39		0.30	3.29	10.39						
Partial Position Change																		

** One Cycle = One Demand

(Composite of 7.4.1 through 7.4.4)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.4 Hydraulic

SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.03	11.12	700.0								6.0 *	16.6	1.38E3	15

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.4 Hydraulic SUBSECTION: 7.4.1 Direct Acting

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		4.0	44.80	500.0	15									5.0 *	262.0	1.38E3	15

CHAPTER: 7 Valve Operators SECTION: 7.4 Hydraulic SUBSECTION: 7.4.2 Double Acting

CHAPTER: 7 Valve Operators SECTION: 7.4 Hydraulic SUBSECTION: 7.4.2 Double Acting

CHAPTER: 7 Valve Operators SECTION: 7.4 Hydraulic SUBSECTION: 7.4.2 Double Acting

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.07	76.9	700.0	15							*	44.0				15

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CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.4 Hydraulic

SUBSECTION: 7.4.3 Geared

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.50	3.05	500.0	15														

CHAPTER: 7 Valve Operators & Actuators	SECTION: 7.4 Hydraulic	SUBSECTION: 7.4.4 Pilot Activated	ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE													
				FAILURE MODE	FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
			ALL MODES	0.03	2.51	500.0	15							6.0 *	10.0	13.0	15

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(Composite of 7.5.1 through 7.5.4)

CHAPTER: 7 Valve Operators
& Actuators

SECTION: 7.5 Mechanical

SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		2.80	16.50	500.0	15					0	4.02	7.28E3	

CHAPTER: 7 Valve Operators & Actuators

SECTION: 7.5 Mechanical

SUBSECTION: 7.5.1 Reverse Acting

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.60	166.7	500.0	15							1.0 *	4.0	7.0	15

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.5 Mechanical SUBSECTION: 7.5.2 Direct Acting

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		2.70	27.0	200.0	15								0	*	1.54E3	6.31E3	15

CHAPTER: 7 Valve Operators & Actuators SECTION: 7.5 Mechanical SUBSECTION: 7.5.3 Geared

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		2.80	27.80	500.0	15							1.0 *	4.0	7.0	15

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CHAPTER: 7 Valve Operators & Actuators SECTION: 7.5 Mechanical SUBSECTION: 7.5.4 Pilot Activated

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		6.0	12.6	40.0	15									8.0 *	1.54E3	7.28E3	15

Chapter 2 Valves and Actuators

D2.1 Introduction. Chapter 2 contains basic information on failure, causes, rates, modes, and outage times of valves and actuators. For those cases where the operator or actuator is not given, refer to Chapter 1 for valve actuators.

This information on driven equipment was gathered by IEEE team visits to nine operating nuclear-power plants. The team visits to these plants were made by at least four IEEE engineers knowledgeable in the field of nuclear power generation. They reviewed and copied maintenance records and complete lists of the plant installation complement of instruments and operating parts, many detailed by subsystems of the plant, for the previous five-year period.

D2.2 Hierarchical Tree. Figure D11(a), (b), (c) is a pictorial representation of the hierarchical structure of Chapter 2 and the procedure in which composites were formed for the various levels of information regarding driven equipment failure rates and outage times.

D2.3 Failure Modes. The failure modes have been developed on the basis of three mode classes: catastrophic, degraded, and incipient,

each of which are further developed into subsidiary classes wherever the available data permits.

D2.4 Failure Reporting. Throughout this data guide failures have been reported for 10E-6 hours or cycles of operation.

The failure rate tables shown in this chapter were taken from the comprehensive ANSI/IEEE Std 500-1984, using the same plates and figures. Therefore the table headings and figures are captioned Chapter 11.2 valves and figures D11, (d), (e) and (f).

D2.5 Valve Component Boundaries. A valve is defined as the valve body and all its internal parts and the valve operator (motor, solenoid, hand wheel, etcetera).

D2.6 Failure Mode Breakdown.

All modes (the sum of catastrophic, degraded, and incipient failure modes catastrophic

Failed to operate

Plugged

External leakage

Degraded

Incipient

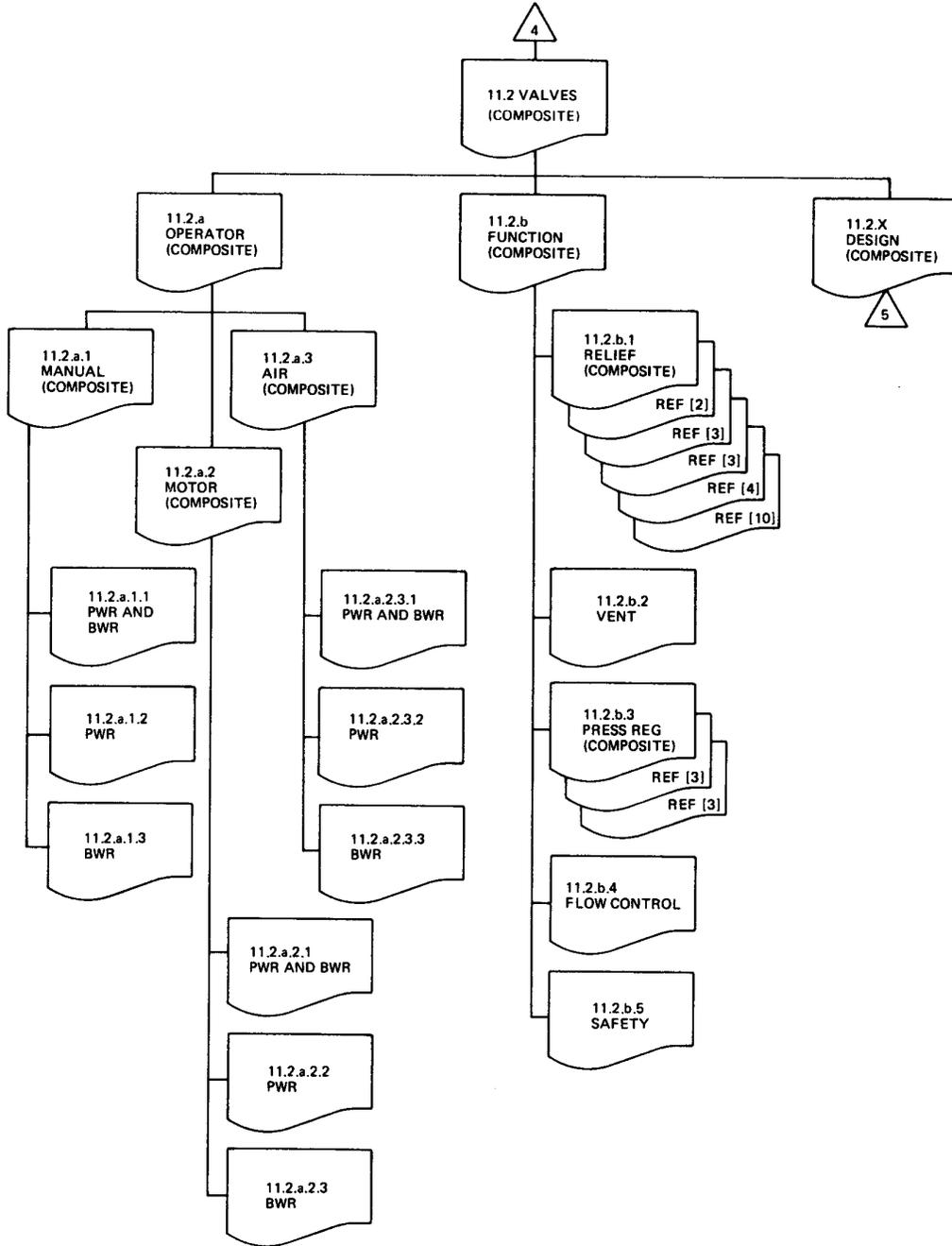


Fig D11 (d)
Valves

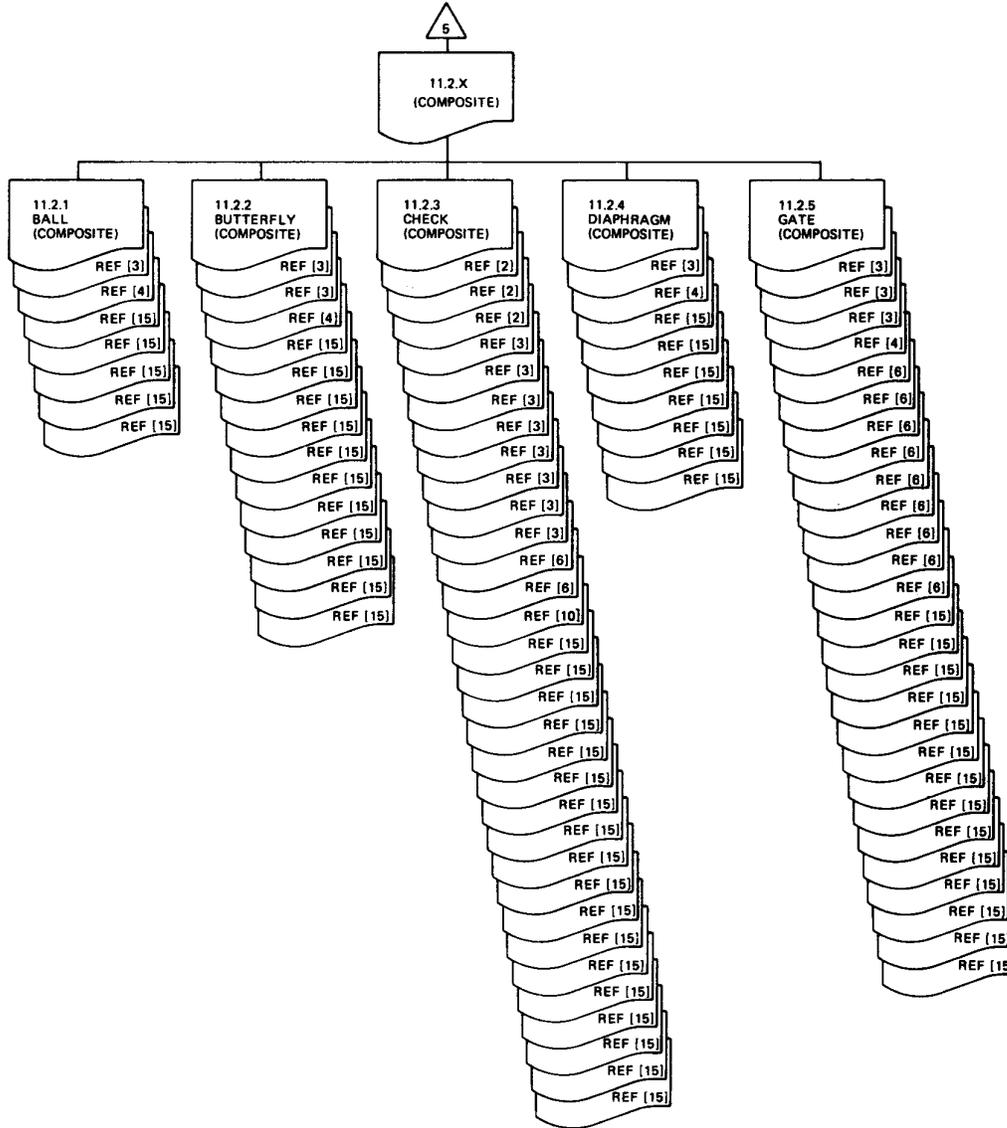


Fig D11 (e)
Valves

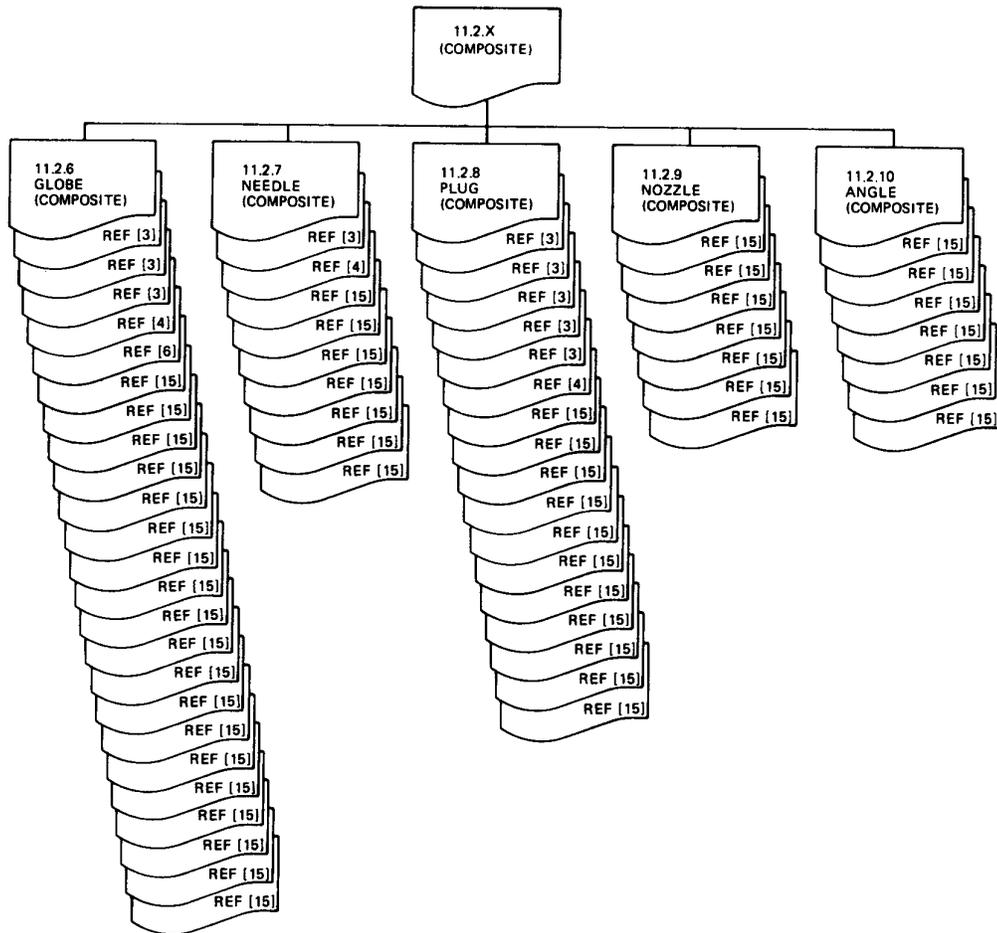


Fig D11 (f)
Valves

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of 11.2.a, 11.2.b and 11.2.X)

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.03	1.39	3.23E3		732					0	* 117.0 0.40 †	8.14E3 476			

VALVE ACTUATORS, AND VALVES

(Composite of 11.2.a.1 through 11.2.a.3)

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.a Operator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (1) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURE MODE						FAILURE RATE						LOW	REC	HIGH	REF
		FAILURE/10 ⁶ HOURS			FAILURE/10 ⁶ CYCLES			LOW	REC	HIGH	REF	LOW	REC				
ALL MODES	Composite	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
			0.07								957						

(Composite of 11.2.a.1.1 through 11.2.a.1.3)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Valves

SUBSECTION: 11.2.a Operator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			0.023								63.2							

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CHAPTER: 11 Driven Equipment	SECTION: 11.1 Valves	SUBSECTION: 11.2.a Operator	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE																		
					FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
			ALL MODES Failed to Operate External Leakage		0.02				2					60									
					0.02									60									

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ITEM OR EQUIPMENT DESCRIPTION		11.2.a.1 Manual, 11.2.a.1.2 PMRs																						
FAILURE MODE	FAILURE RATE	FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)												
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF											
ALL MODES			0.02								70.0													
Failed to Operate			0.02								70.0													
External Leakage																								

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11.2.a.1 Manual, 11.2.a.1.3 BWRs

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES Failed to Operate External Leakage			0.03				2				60.0	2							
			0.03								60.0								

(Composite of 11.2.a.2.1 through 11.2.a.2.3)

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 HOURS					FAILURES/10 CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
11.2.a.2 Motor			0.14								5.77E3							
ALL MODES																		

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SUBSECTION: 11.2.a Operator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF					
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF											
ALL MODES			0.13				2													
CATASTROPHIC			0.13											6.E3						
Failed to Operate														6.E3						
Plugged														6.E3						
External Leakage			0.10																	

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SECTION: 11.2 Valves
SUBSECTION: 11.2.a Operator
ITEM OR EQUIPMENT DESCRIPTION: 11.2.a.2 Motor Operated, 11.2.a.2.2 PWRs

FAILURE MODE	FAILURE RATE											(*) OUT OF SERVICE TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	HIGH	REC	LOW	HIGH	REC	LOW	REC	HIGH	REF	
ALL MODES		0.16		2			4. E3								
CATASTROPHIC		0.16					4. E3								
Failed to Operate		0.06					4. E3								
Plugged		0.10													
External Leakage															

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SUBSECTION: 11.2.a Operator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES CATASTROPHIC Failed to Operate Plugged External Leakage			0.14 0.14 0.06 0.08		2		8.E3 8.E3 8.E3				2						

(Composite of 11.2.a.2.3.1 through 11.2.a.2.2.3.3)

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			0.11								2.45E3							

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES CATASTROPHIC Failed to Operate External Leakage			0.10 0.10 0.10		2			2.E3 2.E3 2.E3							

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SUBSECTION: 11.2.a Operator

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 HOURS					FAILURES/10 CYCLES											
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES CATASTROPHIC Failed to Operate External Leakage			0.07		2		2.E3				2							
			0.07				2.E3											
			0.07				2.E3											

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES CATASTROPHIC Failed to Operate External Leakage			0.20 0.20 0.20		2		3.E3 3.E3 3.E3										

(Composite of 11.2.b.1 through 11.2.b.5)
 CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.b Function

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		1.21	2.37	10.6								†	0.69			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE									(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS			FAILURES/10 ⁶ CYCLES			LOW	HIGH	REF	LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC							HIGH	REF
ALL MODES	11.2.b.1 Relief	1.21	2.27	2.41							†	0.58			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES CATASTROPHIC Failed to Open Premature Open Failed to Seat			4.0		2		13.E3				2							
			4.0				13.E3											
			4.0				10.E3											
							3.E3											

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
11.2.b.1 Relief, 3/4 Inch 150 Pounds, Set at 80 psi 5 gpm	ALL MODES	1.1	1.68	2.41	3							†	0.40				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
11.2.b.1 Relief, 1/2 Inch 150 Pounds	ALL MODES	1.21	1.61	1.81	3							† 0.40			3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			5.0		10		3.2E3		10								

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
11.2.b.2 Vent, 3/4 Inch, Float Operated, Tank Vent			3.11		3							† 1.20				3
ALL MODES																

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(Composite of Ref 3)
CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.b Function

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		2.0	3.19	10.6								†	1.19			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
ALL MODES		2.87			3					†	1.30			3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES										
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES		2.88	3.33	3.62	3									† 1.30			3

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				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH
ALL MODES	2.0	5.54	10.63	3	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	1.0	3

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ITEM OR EQUIPMENT DESCRIPTION		FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
			FAILURE MODE						FAILURE RATE								
			FAILURE MODE						FAILURE RATE								
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
		FAILURE MODE						FAILURE RATE									
CHAPTER: 11 Driven Equipment		SECTION: 11.2 Valves		SUBSECTION: 11.2.b Function													
ITEM OR EQUIPMENT DESCRIPTION		11.2.b.5 Safety															
ALL MODES																	
CATASTROPHIC																	
Failed to Open																	
Premature Open																	

(Composite of 11.2.1 through 11.2.10)
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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)									
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES														
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		0.03	2.85	3.23E3						76				0	* 117.0	8.14E3		0.40	† 1.38	476	

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SUBSECTION: 11.2.1 Ball

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES		0.44	2.37	877.0					60					105.0	* 447.0	5.91E3			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Valve Ball, 1 Inch 200 Pounds	ALL MODES		1.21		3							†	1.25				3

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SUBSECTION: 11.2.1 Ball

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			0.65		4												

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.44	4.39	439.0	15							* 176.0					15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.37	2.50	25.0	15							105.0	* 462.0	818.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES	Electric, Motor/Servo 2 - 3.99 In	0.45	3.03	30.3	15							* 264.0				15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Electric, Motor/Servo 4 - 11.99 In	1.78	8.88	53.3	15								5.0 *	2.02E3	5.91E3	15	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Manual, 40 - 59.99 In	0.88	8.77	877.0	15													* 415	.15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF											
ALL MODES		0.03	1.16	345.0									0	* 729	5.11E3		1.3	† 1.89	2.1	

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SECTION: 11.2 Valves

SUBSECTION: 11.2.2 Butterfly

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
8 In, 300 Pounds			2.41										† 2.1				3
ALL MODES					3												

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES				LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		1.21	2.41	3.62	3					1.30 †	1.70	2.10	3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			1.32		4												

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES									
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES		5.17	34.5	345.0	15								2.0 *	3.0	4.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		5.17	10.4	20.7	15									2.0 *	10.0	40.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm Cylinder, 20 - 39.99 In	4.22	7.03	10.9	15							0	* 413.0	5.11E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		2.65	4.41	6.84	15							1.0	* 637.0	4.25E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (1) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm Cylinder, 4 - 11.99 In	0.81	1.62	3.24	15							2.0	* 644.0	4.25E3	15

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					FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
																	18.0	* 173.0	445.0
			Electric Motor/Servo 20 - 39.99 In	ALL MODES	2.79	6.97	17.4	15											

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		0.20	1.0	6.0	15									7.0 *	82.0	119.0	15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.2 Butterfly

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Electric Motor/Servo 4 - 11.99 In	ALL MODES	0.82	2.72	8.57	15							3.0 *	31.0	48.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.79	1.98	19.8	15							596.0 *	2.57E3	4.53E3	15

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SECTION: 11.2 Valves

SUBSECTION: 11.2.2 Butterfly

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Manual 12 - 19.99 In	0.43	1.07	2.67	15							193.0	* 695.0	1.08E3	15

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SUBSECTION: 11.2.2 Butterfly

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.03	0.21	2.1	15							*	1.27E3			15

(Composite of Ref 2, 3, 6, 10 and 15)

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.08	2.08	327.0						96.0			0	* 140 0.80 †	7.25E3 24.0		

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ITEM OR EQUIPMENT DESCRIPTION PMRs and BWRs	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES CATASTROPHIC Failed to Open Internal Leakage External Leakage			0.55 0.55 0.50 0.05				2				60 60 60							

CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			0.44		2		60											
CATASTROPHIC			0.44				60											
Failed to Open			0.40				60											
Internal Leakage			0.04															
External Leakage																		

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			0.98				2				80							
CATASTROPHIC			0.98								80							
Failed to Open											80							
Internal Leakage			0.90															
External Leakage			0.08															

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)											
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES																
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC		HIGH	REF									
ALL MODES			3.18		3																		

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Swing, 10 Inches, 175 Pounds	2.41	3.62	4.82	3								†	1.50			3

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SECTION: 11.2 Valves

SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
Swing, 6 Inches, 150 Pounds	ALL MODES	0.60	1.90	3.01	3							†	0.90			3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Swing, 1 - 2 Inches, 150 Pounds	ALL MODES	2.40	3.24	6.03	3							†	0.90				3

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SECTION: 11.2 Valves

SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
Swing, 1/2 Inch, 200 Pounds	ALL MODES	1.0	2.21	6.0	3							†	0.80			3

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SECTION: 11.2 Valves
SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Spring Loaded, 8 Inches, 150 Pounds	ALL MODES	2.41	2.61	2.83	3							0.80 †	1.20	1.70	3

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SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)									
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES															
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
Spring Loaded, 6 Inches, 150 Pounds			2.56		3									†	1.10							3	
ALL MODES																							

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Spring Loaded, 4 Inches, 150 Pounds		3.01									†	1.0				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Residual Heat Removal, 24 Inches			31.3		6							† 11.9	24		6
ALL MODES															

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE															
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES		17.8			6									† 15.3	16		6

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF					
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF											
ALL MODES			0.52				10				290.0				10					

(Composite of Ref 15)

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.08	1.26	327								0	140.0	7.25E3			

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SECTION: 11.2 Valves

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
20 - 39.99 Inches	ALL MODES	17.3	43.2	108.0	15							52.0	* 167.0	294.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		6.55	10.9	16.4	15							0	* 776.0	4.19E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.04	2.97	8.17	15							46.0	* 610.0	1.2E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.26	2.10	3.36	15							2.0	* 816.0	4.2E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.83	1.39	2.22	15							0	*	1.1E3	4.24E3	15

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ITEM OR EQUIPMENT DESCRIPTION 2 - 3.99 Inches

FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	0.82	1.37	2.12	15							0	* 999.0	7.25E3	15

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SUBSECTION: 11.2.3 Check

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		1.25	2.28	4.33	15									2.0 *	534.0	2.06E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE														
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES		2.06	8.25	33.0	15					1.0	* 685.0	2.14E3	15			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.90	3.79	7.58	15									2.0 *	565.0	1.28E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
	ALL MODES	0.19	0.63	1.98	15								0	*	49.0	115.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.08	0.55	5.50	15									39.0	* 659.0	1.28E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
	ALL MODES	0.10	0.64	6.40	15									68.0 *	94.0	120.0	15

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SECTION: 11.2 Valves

SUBSECTION: 11.2.3 Checks

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Solenoid 20 - 39.99 Inches	20.4	81.6	327.0	15									538.0 *	1.13E3	1.32E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		5.96	10.5	20.6	15									0	* 564.0	4.27E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Pneumatic Diaphragm Cylinder, 12 - 19.99 Inches		2.73	4.97	9.44	15							7.0	* 623.0	3.53E3	15
ALL MODES															

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE															
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
														LOW	HIGH	REF	
ALL MODES		1.48	4.94	15.6	15									8.0	* 327.0	1.42E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Manual, 4 - 11.99 Inches	ALL MODES	0.43	0.85	1.91	15							96.0 *	2.46E3	6.02E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Manual, 2 - 3.99 Inches	ALL MODES	0.22	0.55	1.38	15							3.0 *	1.98E3	6.63E3	15

(Composite of Ref 3, 4 and 5)

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Equipment

SECTION: 11.2 Valves

SUBSECTION: 11.2.4 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.19	2.83	61.9									0	* †	97.0 0.90	7.51E3	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES			2.41						3					†	0.90				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			2.62		4												

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SECTION: 11.2 Valves
SUBSECTION: 11.2.4 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		2.06	10.3	61.9	15												

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SUBSECTION: 11.2.4 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Solenoid, 1/2 - 1.99 Inches	3.72	8.26	19.0	15								1.0	* 422.0	1.32E3	15	

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CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.4 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION: Pneumatic/Diaphragm/Cylinder, 4 - 11.99 Inches

FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	5.72	11.4	24.6	15							497.0 *	1.29E3	2.69E3	15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.4 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Pneumatic/Diaphragm/Cylinder, 2 - 3.99 Inches	3.06	5.09	8.14	15								1.0 *	1.16E3	6.67E3	15	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.24	3.54	9.74	15							25.0 *	83.0	209.0	15

CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.4 Diaphragm

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES										
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC		HIGH	REF			
Electric Motor/Servo, 2 - 3.99 Inches	ALL MODES	1.86	7.42	29.7	15									35.0 *	81.0	126.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE														
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		LOW	REC	HIGH	REF	LOW	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES	Manual, 2 - 3.99 Inches	1.19	1.98	2.87	15							0	* 317.0	7.51E3	15	

(Composite of Ref 3, 4, 6 and 15)

CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.5 Gate

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.17	1.85	46.1								0	* 387	7.73E3			
												0.40 †	3.32	476			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	10 Inches, 175 Pounds	1.44	1.60	1.81	3							0.40 †	0.80	1.20	3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
3, 4 Inches, 175 Pounds	ALL MODES	0.30	0.66	0.84	3							1.10 †	1.40	1.80	3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
1/2 - 2 Inches, 200 Pounds	ALL MODES	0.60	0.21	0.92	3							†	0.80	0.90	3

CHAPTER: 11 Driven Equipment

SECTION: 11.2 Valves

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
	ALL MODES		1.34		4														

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
Residual Heat Removal, 16 Inches	ALL MODES		25.0		6							†	15.70	40.0		6

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SUBSECTION: 11.2.5 Gate

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Residual Heat Removal, 18 Inches			1.78		6								† 4.0				6
ALL MODES																	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES	Residual Heat Removal, 20 Inches		17.8		6							†	10.3	24.0		6

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SECTION: 11.2 Valves
SUBSECTION: 11.2.5 Gate

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
Residual Heat Removal, 24 Inches	ALL MODES		8.83				6						† 225.0	476.0		6

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
Core Spray, 16 Inches	ALL MODES		53.6		6							†	9.0	27.0		6

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REC	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			71.50			6								† 10.0	26.0		6

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
ALL MODES			89.4		6							† 13.20	40.0	6

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES	High Pressure Cooling Injection, 16 Inches		17.8			6							† 11.0	20.0		6

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE																		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		LOW	REC	HIGH	REF.	LOW	REF.	LOW	REC	HIGH	REF.	LOW	REC	HIGH	REF.					
CONDENSATE AND FEEDWATER, 18 INCHES	ALL MODES		10.9		6												†	7.80	10.90	6

RELIABILITY DATA FOR PUMPS AND DRIVERS,

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.17	1.49	46.1								0	* 387.0	7.73E3	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Solenoid, 4 - 11.99 Inches	17.9	29.7	46.1	15							2.0	* 270.0	2.81E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Pneumatic/Diaphragm/Cylinder, 20 - 39.99 Inches	ALL MODES	8.0	16.0	34.4	15							0	* 284.0	1.20E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm/Cylinder, 4 - 11.99 Inches	1.40	3.49	8.73	15							24.0	* 430.0	792.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm/Cylinder, 2 - 3.99 Inches	2.27	4.54	10.2	15							3.0	* 482.0	2.47E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
		0.26	1.72	17.20	15									14.0	* 145.0	275.0	15
ALL MODES																	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Electric Motor/Servo, 20 - 39.99 Inches	ALL MODES	1.73	3.15	5.99	15							1.0	* 362.0	4.87E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Electric Motor/Servo, 12 - 19.99 Inches	1.62	2.70	3.92	15							0	* 338.0	5.80E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE							(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES			LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH				
ALL MODES	Electric Motor/Servo, 4 - 11.99 Inches	1.75	2.33	3.26	15				0	* 606.0	7.73E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Electric Motor/Servo, 2 - 3.99 Inches		3.48	4.64	6.50	15								1.0 *	562.0	4.13E3	15	
ALL MODES																	

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SUBSECTION: 11.2.5 Gate

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES										
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES	Electric Motor/Servo, 1/2 - 1.99 Inches	0.85	2.44	6.71	15									7.0 *	98.0	178.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE																		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		1.03	1.72	2.75	15												3.0	* 401.0	1.92E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Manua], 4 - 11.99 Inches	ALL MODES	0.18	0.33	0.63	15								22.0 *	2.1E3	7.88E3	15	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Manual, 2 - 3.99 Inches		0.43	0.72	1.12	15							3.0 *	641.0	5.94E3	15
ALL MODES															

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.17	0.34	0.77	15							21.0 *	1.06E3	7.20E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.18	3.53	174.0								1.0	1.93	7.01E3			
												*	1.71				

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SECTION: 11.2 Valves
SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES	6 Inches, 150 Pounds		1.59			3							†	1.20				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
2 Inches, 175 Pounds	ALL MODES		1.21		3							†	0.90				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
1 Inch, 200 Pounds	ALL MODES		1.21		3							†	0.80				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES			0.17				4												

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Reactor Core Isolation Cooling, 10 Inches	ALL MODES		17.8		6							†	10.0				6

(Composite of Ref 15)

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ITEM OR EQUIPMENT DESCRIPTION

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FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	0.18	2.96	174.0								1.0 *	193.0	7.01E3	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.99	7.79	31.9	15							1.0 *	181.0	360.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		3.09	6.19	13.3	15							8.0 *	97.0	661.0	15

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SECTION: 11.2 Valves

SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.93	2.65	7.29	15							4.0	* 161.0	360.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE															
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		1.73	4.93	13.6	15									2.0	* 495.0	2.85E3	15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Solenoid, 4 - 11.99 Inches	14.4	24.0	38.4	15							2.0 *	422.0	1.65E3	15

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SECTION: 11.2 Valves
SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Solenoid, 2 - 3.99 Inches	0.72	2.89	11.6	15							5.0	* 965.0	2.60E3	15

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SECTION: 11.2 Valves

SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE							(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS				FAILURES/10 ⁶ CYCLES			LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH				
ALL MODES	Pneumatic/Diaphragm/Cylinder, 20 - 39.99 Inches	4.39	8.79	18.9	15				2.0 *	1.0E3	2.38E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm/Cylinder, 12 - 19.99 Inches	0.19	0.25	0.35	15							1.0 *	1.02E3	7.01E3	15

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SECTION: 11.2 Valves

SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Pneumatic/Diaphragm/Cylinder, 4 - 11.99 Inches	7.29	9.72	13.6	15								1.0	* 947.0	6.08E3	15	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm/Cylinder, 2 - 3.99 Inches	4.46	5.57	7.24	15							1.0 *	830.0	6.36E3	15

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SECTION: 11.2 Valves

SUBSECTION: 11.2.6 Globe

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Pneumatic/Diaphragm/Cylinder, 1/2 - 1.99 Inches	ALL MODES	0.79	1.32	2.05	15							0	* 475.0	5.41E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Hydraulic, 12 - 19.99 Inches	22.1	63.2	174	15									7.0	* 321.0	861.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Hydraulic, 4 - 11.99 Inches	5.16	10.3	22.2	15							2.0 *	59.0	183.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Electric Motor/Servo, 12 - 19.99 Inches	2.82	5.13	9.75	15							4.0 *	154.0	724.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		2.31	4.20	7.98	15							3.0 *	357.0	3.31E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
	ALL MODES	1.77	2.95	4.57	15							0	* 557.0	5.04E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
Electric Motor/Servo, 1/2 - 1.99 Inches	ALL MODES	1.54	3.09	6.64	15								4.0 *	1.10E3	5.47E3	15	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE														
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
Manual, 2 - 3.99 Inches	ALL MODES	0.18	0.30	0.48	15								1.0	* 952.0	8.09E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE															
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
Manual, 1/2 - 1.99 Inches	ALL MODES	0.18	0.30	0.48	15									8.0 *	946.0	5.73E3	15

(Composite of Ref 3, 4 and 15)

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SUBSECTION: 11.2.7 Needle

ITEM OR EQUIPMENT DESCRIPTION

FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	HIGH	REF	
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES	0.09	1.21	417.0										0	* 10.1 † 0.80	2.76E3	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
1/4 Inch, 3000 psi	ALL MODES		1.67		3							†	0.80				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			1.36		4													

(Composite of Ref 15)

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.09	0.76	417.0								0	*	10.1	2.76E3	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES	Solenoid, 1/2 - 1.99 Inches	6.25	41.7	417.0	15								0	*	24.0	48.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES									
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH
Manual, Solenoid Under 1/2 Inch	ALL MODES	0.33	3.34	334.0	15								*	6.0		15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Hydraulic, 4 - 11.99 Inches	1.56	7.79	46.8	15							24.0 *	817.0	2.36E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Hydraulic, 1/2 - 1.99 Inches	4.45	8.90	19.2	15							5.0	* 558.0	2.76E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.09	0.90	90.0	15							*	7.0				15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Manual, 1/2 - 1.99 Inches	ALL MODES	0.12	0.49	1.96	15							10.0 *	21.0	42.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.36	3.62	362.0	15							*	2.0	15	

(Composite of Ref 3, 4, and 15)

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SECTION: 11.2 Valves

SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.14	2.58	3.23E3								1.0 * 0.5 †	246 1.19	6.08E3 2.2	15 3

(Composite of Ref 3)

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SECTION: 11.2 Valves

SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION

FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	0.97	2.03	5.76								0.50 †	1.19	2.20	

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SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
6 Inches, 150 Pounds	ALL MODES		2.40		3							†	1.80				3

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SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	4 Inches, 150 Pounds		1.19		3							†	0.90				3

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SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES		1.21	4.46	5.76	3									†	0.90				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES			0.97			3								†	0.50				3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.97	1.75	3.84	3							0.50 †	1.50	2.20	3

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		3.27			4												

(Composite of Ref 15)
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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.14	2.46	3.23E3								1.0 *	246.0	6.08E3	

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
	ALL MODES	0.94	9.43	943.0	15									* 403.0				15

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ITEM OR EQUIPMENT DESCRIPTION Mechanical Differential Pressure, 4 - 11.99 Inches

FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	0.48	1.92	7.68	15							1.0 *	97.0	244.0	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		11.8	19.7	31.5	15							7.0 *	1.23E3	6.08E3	15

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SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Mechanical Differential Pressure, 1/2 - 1.99 Inches	ALL MODES	0.83	1.66	3.74	15							1.0 *	888.0	5.39E3	15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES										
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES	Solenoid, 1/2 - 1.99 Inches	0.74	7.35	735.0	15								*	2.14E3			15

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Solenoid, Under 1/2 Inch	2.39	5.31	12.2	15							8.0	* 449.0	1.60E3	15

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SECTION: 11.2 Valves
SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Pneumatic/Diaphragm/Cylinder, 4 - 11.99 Inches	ALL MODES	2.59	6.49	16.2	15							50.0	* 474.0	1.13E3	15

CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Pneumatic/Diaphragm, Cylinder, 1/2 - 1.99 Inches	0.14	0.95	9.50	15							16.0 *	30.0	44.0	15

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		3.2	32.3	3.23E3	15							*	2.0			15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Hydraulic, 4 - 11.99 Inches	0.88	88.7	877	15							*	8.0				15

VALVE ACTUATORS, AND VALVES

CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.8 Plug

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Hydraulic, 2 - 3.99 Inches	2.63	17.6	175	15							6.0 *	23.0	40.0	15

(Composite of Ref 15)
 CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.32	5.41	645								4.0 *	82.9	8.14E3		

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		4.58	9.16	19.7	15							28.0	* 856.0	3.67E3	15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		0.65	6.45	645	15							* 174.0				15

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (1) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.40	4.02	402	15							*	74.0				15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Mechanical Differential Pressure, 4 - 11.99 Inches	2.38	4.71	7.54	15							4.0 *	1118.0	373.0	15

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CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.99	3.98	8.56	15							6.0 *	2.25E3	18.14E3	15

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
ALL MODES	Mechanical Differential Pressure, 1/2 - 1.99 Inches	4.81	8.75	16.6	15							13.0 * 378.0	4.89E3	15

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.9 Nozzle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
Electric Motor/Servo	ALL MODES	0.32	3.19	319.0	15							*	8.0			15

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of Ref 15)
 CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.25	3.27	2.33E3								0	* 35.7	736.0	

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CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION
Electric Motor/Servo, 4 - 11.99 Inches

FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
	FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						LOW	REC	HIGH	REF	
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
ALL MODES	0.5	2.53	253	15									* 248.0				15

CHAPTER: 11 Driven Equipment
SECTION: 11.2 Valves
SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
Pneumatic/Diaphragm/Cylinder, 2 - 3.99 Inches	ALL MODES	1.54	10.3	103.0	15							0	* 13.0	25.0	15

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES	Pneumatic/Diaphragm/Cylinder, 20 - 39.99 Inches	1.70	17.0	1.70E3	15							*	3.0				15

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE													
		FAILURES/10 ⁶ HOURS						FAILURES/10 ⁶ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF		
ALL MODES	Solenoid, 1/2 - 1.99 Inches	2.3	23.3	2.33E3	15									* 336.0	15

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES										
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES		0.86	2.45	6.74	15									17.0 *	45.0	111.0	15

CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		7.87	19.7	49.2	15							2.0 *	121.0	736.0	15

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CHAPTER: 11 Driven Equipment SECTION: 11.2 Valves SUBSECTION: 11.2.10 Angle

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		1.26	3.14	7.85	15							9.0 *	140.0	200.0	15

Chapter 3 Pumps and Drivers

D3.1 Introduction. Chapter 3 contains basic information on failure causes, failure rates, failure modes, and outage times of pumps which can be driven electrically, hydraulically, by diesel or turbines.

This information on driven equipment was gathered by IEEE team visits to nine operating power plants. The team visits to these plants were made by at least four IEEE engineers knowledgeable in the field of power generation. They reviewed and copied maintenance records and complete lists of the plant installation complement of instruments and operating parts, many detailed by subsystems of the plant, for the previous five-year period, plus the previous Delphi data.

D3.2 Hierarchical Tree. Figure D11 is a pictorial representation of the hierarchical structure of Chapter 11 and the procedure in which composites were formed for the various levels of information regarding driven equipment failure rates and outage times.

D3.3 Failure Modes. The failure modes have been developed on the basis of three mode classes: catastrophic, degraded, and incipient, each of which are further developed into subsidiary classes wherever the available data permits.

D3.4 Failure Reporting. Throughout this data guide failures have been reported for $10E-6$ hours or cycles of operation. In this chapter, however, in the section on pumps, 11.1, the units have been changed to $10E-3$ for failures/10⁶ cycles. Please take note of this change when using these tables.

The failure rate tables shown in this chapter were taken from the comprehensive ANSI/IEEE Std 500-1984, using the same plates and figures. Therefore the table headings and figures are captioned Chapter 11.1, Pumps and figures D11 (a), (b) and (c).

D3.5 System definitions. We define the pump component as the pumping unit and its associated prime mover coupling and mechanical

controls, excluding switches, circuit breakers, and sensing devices.

D3.6 Categories of Systems. In order to better represent the populations of pumps that have different operating characteristics, we found it necessary to divide the systems that contained the pumps of interest into three different categories. The systems and their codes are listed by category in Table 1. We recognize that some of the systems could belong to more than one category. For example, Auxiliary Feed, and Residual Heat Removal could at times fall into the Alternating category. However, the duration that these systems fall into the Alternating category is short compared to that in the Standby mode. So, we identified the pumps within these systems as Standby pumps.

Alternating Systems

We define an Alternating system as any system in which the pumps are periodically alternated between standby and operating status while the reactor is critical. Examples of this kind of system are the Component Cooling Water and Service Water systems. Consequently, the pumps within these systems are categorized as Alternating pumps.

Standby Systems

We define a Standby system as any system in which the pumps are normally in a standby condition during critical operation. Examples of these systems are the Containment Spray and Core Spray systems. Consequently, the pumps within these systems are categorized as Standby pumps.

Also, some systems may vary between categories, depending on the plant in question. However, for this analysis, we assume that the systems in all plants can be categorized according to Table 1. We also consider the standby systems to be representative of the safety systems in PWRs and BWRs.

TABLE 1. SYSTEM CATEGORIES

<u>PWR System (Code)</u>		<u>BWR System (Code)</u>
	<u>Running</u>	
Reactor Coolant		Coolant Recirculation
	<u>Alternating</u>	
Component Cooling Water		Component Cooling Water
Chemical Volume Control		Service Water
Boric Acid Transfer		
Service Water		
	<u>Standby</u>	
Auxiliary Feed		Core Spray
Containment Spray		Containment Spray
High Pressure Coolant Injection (H)		High Pressure Coolant Injection
Low Pressure Coolant Injection/ Residual Heat Removal (L)		Low Pressure Coolant Injection/ Residual Heat Removal
		Reactor Core Isolation Cooling
		Standby Liquid Control

D3.6 The following listing of failure mode categories occur under the component listings in Chapter 3.

Pumps and Drivers Failure Modes Breakdown

- (1) *Pumps*
 All modes (sum of catastrophic, degraded and incipient)
 Catastrophic
 Fails while running
 Fails to start
 Degraded
 Out of specification
 Incipient

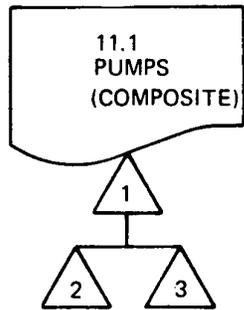


Fig D11
Hierarchical Tree
Pumps and Drivers

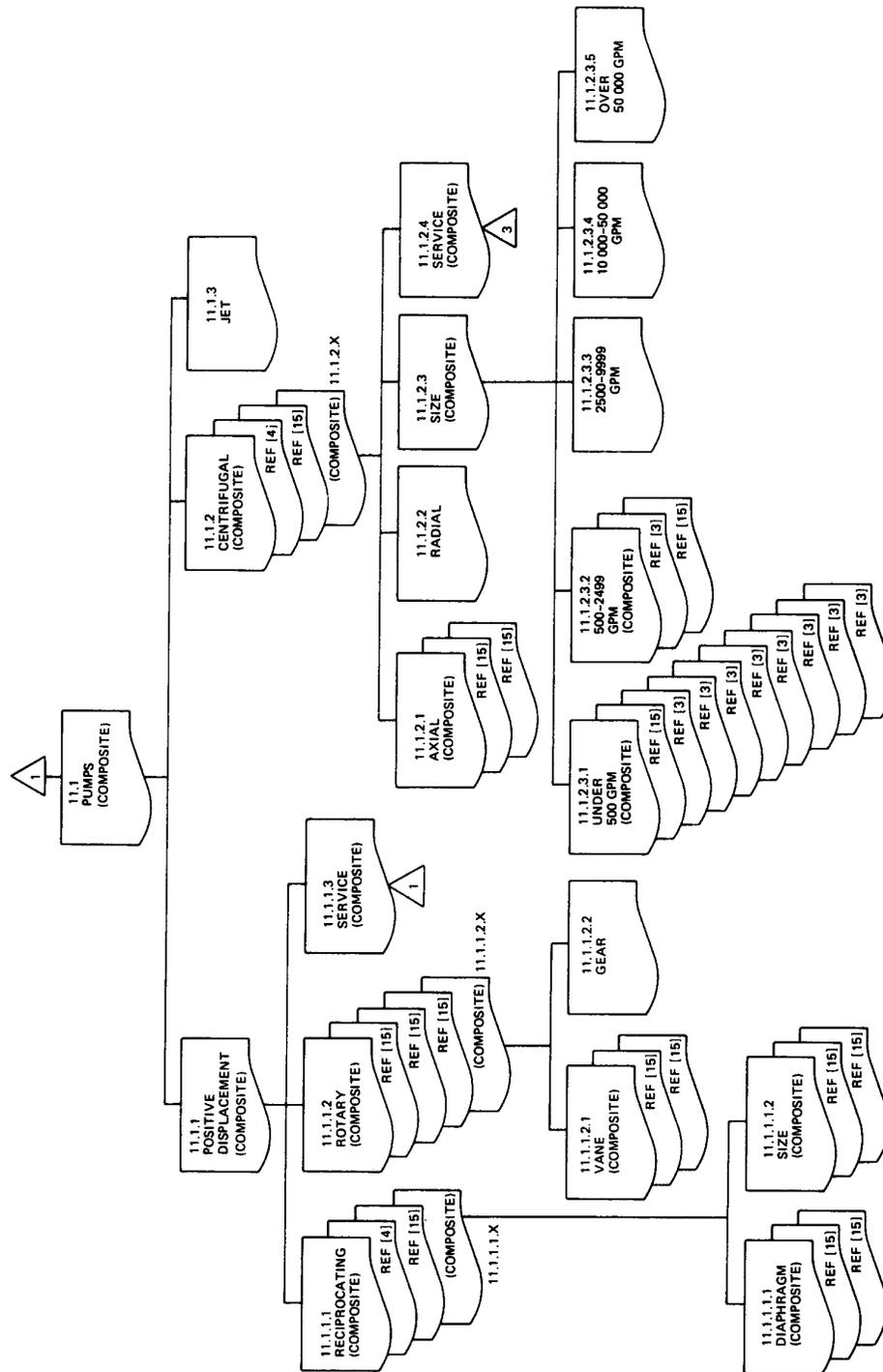


Fig D11 (a)
Pumps

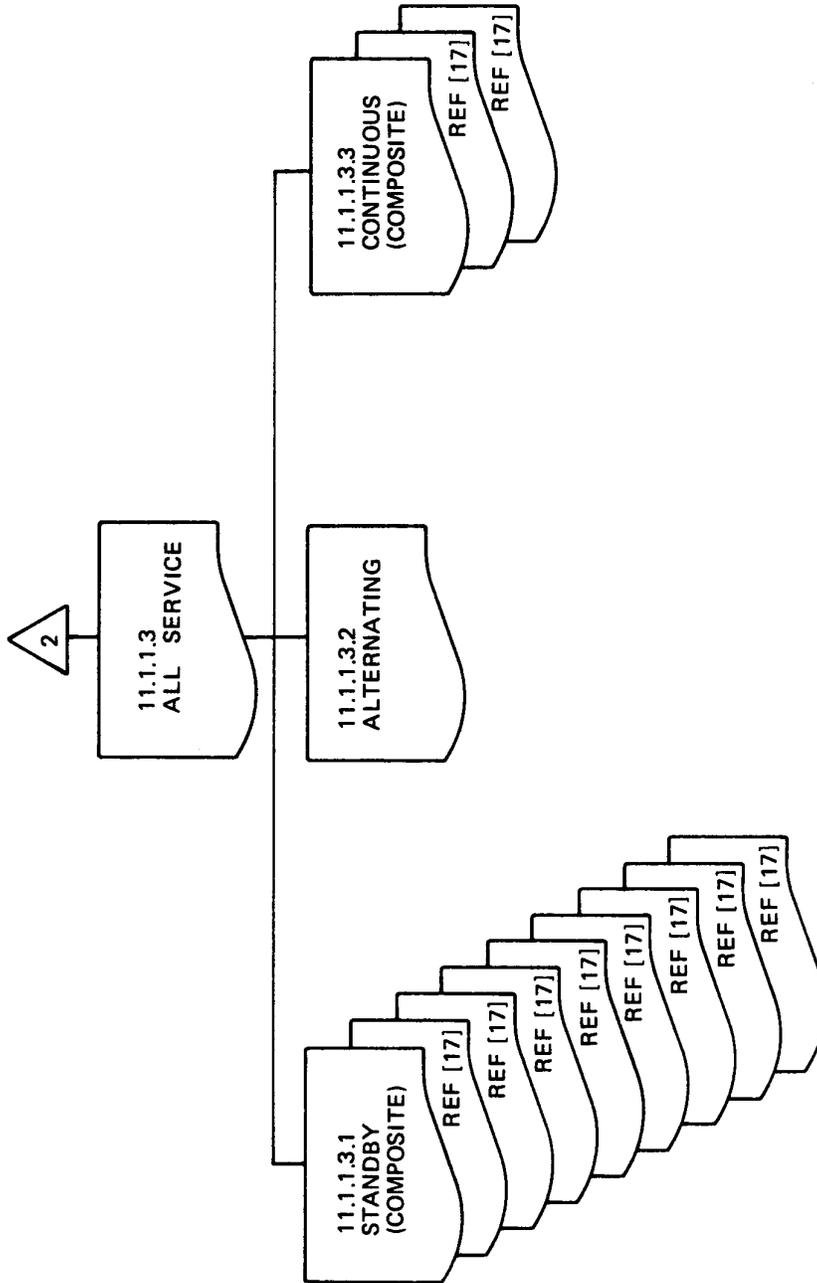


Fig D11 (b)
Pumps
Positive Displacement

VALVE ACTUATORS, AND VALVES

(Composite of 11.1.1.1 through 11.1.1.3)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0.45	22.42	1.98E3		0	93.9	530.0		6.0 *	121.0	4.93E3					
CATASTROPHIC		0	1.93	235.5		0	19.2	160.4		1.0 †	7.39	300.0					
Fails While Running		0	1.93	235.5		0	19.2	160.4									
Fails to Start		0	0.23	372.5		0	2.59	160.4									
DEGRADED		0.45	20.25	1.37E3		0	72.10	209.20									
INCIPIENT																	

RELIABILITY DATA FOR PUMPS AND DRIVERS,

(Composite of Ref 4, 15 and 11.1.1.1.1.X)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
11.1.1.1 Reciprocating Composite	ALL MODES	3.07	10.59	790.0								0	*	95.45	4.93E3	

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement								
ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE				(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
FAILURE MODE		FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC				
11.1.1.1.1.1 Diaphragm, Under 500 GPM		94.0	316.0	790.0	15				12.0 * 757.0	3.65E3	15
ALL MODES											

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	FAILURE RATE																		
				FAILURE MODE	FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
				11.1.1.1.1.2	Diaphragm, 500 - 2499 GPM	4.55	18.2	180.0	15								*	42.0				15
				ALL MODES																		

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(Composite of Ref 15)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.1 Positive Displacement

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH
11.1.1.1.1 Reciprocating, 11.1.1.1.2 Size Composite	ALL MODES	3.29	107.0	250									0	* 1115.0	4.93E3	

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
				11.1.1.1.2.1 Reciprocating, Under 500 GPM	204.0	227.0	250.0	15							0	*140.0	4.93E3	15
				ALL MODES														

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF		
		LOW	REC	HIGH	REF	15	LOW	REC	HIGH	REF						
CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement 11.1.1.1.2.2 Reciprocating, 500 - 2499 GPM	ALL MODES	3.29	13.2	132.0	15							*	95.0			15

(Composite of Ref 15 and 11.1.1.2.X)

CHAPTER: 11 Driven
Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.1. Positive
Displacement

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		0.45	20.9	196.0								0	* 126.0	808.0	

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment 11.1.1.2.1.1 Rotary	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
				FAILURE MODE					LOW	REC	HIGH	REF
				FAILURES/10 ⁶ HOURS		FAILURES/10 ³ CYCLES						
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES	3.89	15.6	62.2	15								

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION Rotary, Under 500 GPM	FAILURE RATE														
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES				14.3	28.6	43.0	15							0	*	81.0	355.0	15

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	Rotary, 2500 - 9999 GPM	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	FAILURE RATE																	
				FAILURE MODE					FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
				FAILURE MODE					FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES											
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES					4.90	19.6	196.0	15					16.0	* 412.0	808.0						15

(Composite of 11.1.1.2.1 and 11.1.1.2.2)

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC.	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
11.1.1.2 Rotary, 11.1.1.2.X Composite of Vane and Gear		0.45	7.74	175.0										11.0 *	124.0	184.0	
ALL MODES																	

CHAPTER: 11 Driver Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		4.39	30.6	175.0								11.0 *	12.50	184.0	

(Composite of Ref 15)
CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement
11.1.1.2 Rotary, 11.1.1.2.1 Vane Composite

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	Vane Type, Under 500 GPM	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
					FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES					11.29	37.6	75.3	15									11.0 *	78.0	184.0	15			

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement

ITEM OR EQUIPMENT DESCRIPTION	Vane Type	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
			FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES			4.39	17.5	175.0	15							*	2.0			15

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1. Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
			11.1.1.2 Rotary, 11.1.1.2.2 Gear		0.45	1.81	181.0	15							*	1.23E3			15	
			ALL MODES																	

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(Composite of 11.1.1.3.1 through 11.1.1.3.3)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.1 Positive Displacement

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURE MODE						FAILURE RATE						LOW	HIGH	REF	
	FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC				HIGH
ALL MODES	2.20	310.0	1.98E3				0	93.86	530.0			1.0 †	7.39	300		
CATASTROPHIC	0	26.7	236.0				0	19.2	160.0							
Fails While Running	0	26.7	236.0				0	19.15	160.0							
Fails to Start	0	3.16	373.0				0	2.59	161.0							
DEGRADED	2.20	280.5	1.37E3				0	72.10	209.0							
INCIPIENT																

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.1 Positive Displacement

ITEM OR EQUIPMENT DESCRIPTION: 11.1.1.3 Service, 11.1.1.3.1 Standby

FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES					0	33.0	530.0			6.0 †	6.74	10.0		
CATASTROPHIC					0	5.36	160.0							
Fails to Start					0	5.36	160.0							
DEGRADED					0	6.42	161.0							
INCIPIENT					0	20.48	209.20							

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CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
					FAILURE MODE					FAILURE RATE					LOW	REC	HIGH	REF					
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF											
			11.1.1.3 Service, 11.1.1.3.1 Standby Service, Standby Liquid Control, Motor Driven, Including Driver																				
			ALL MODES																				
			CATASTROPHIC																				
			Fails to Start																				
			DEGRADED																				
			INCIPIENT																				

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION 11.1.1.3 Service, 11.1.1.3.1 Standby Service, Liquid Control, Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
				FAILURE MODE					FAILURE RATE					LOW	HIGH	REF			
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	HIGH				REF		
ALL MODES										33.0	66.20	152.0							
CATASTROPHIC										0	3.20	42.0							
Fails to Start										0	1.60	21.0							
DEGRADED										0	1.60	21.0							
INCIPIENT										33.0	63.0	110.0							

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.1 Positive Displacement							
ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
FAILURE MODE		FAILURE RATE			FAILURE RATE			LOW	REC	HIGH	REF
		FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES						
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES				4.6	32.0	160.0	17	†	12.0		17
CATASTROPHIC				0	3.0	39.0					
Fails to Start				0	3.0	39.0					
DEGRADED				4.60	26.0	82.0					
INCIPIENT				0	3.0	39.0					

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION 11.1.1.3 Service, 11.1.1.3.1 Standby Service, Diesel Generator Fuel, Diesel Driven Includes Driver	FAILURE RATE												(*) OUT OF SERVICE (#) REPAIR TIME OR (#) RESTORE (HOURS)										
				FAILURE MODE						FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF	
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES																										
CATASTROPHIC																										
Fails to Start																										
DEGRADED																										
INCIPIENT																										

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement						
ITEM OR EQUIPMENT DESCRIPTION									
11.1.1.3 Service, 11.1.1.3.1 Standby Service, Feed Water, Emergency, Lub Oil, Motor Driven Includes Driver									
FAILURE MODE	FAILURE RATE				(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
	FAILURES/10 ⁶ HOURS		FAILURES/10 ³ CYCLES						
	LOW	HIGH	LOW	HIGH					
ALL MODES			0.43	12.1	90.0	17			
CATASTROPHIC			0	1.9	25.0				
Fails to Start			0	1.9	25.0				
DEGRADED			0	1.9	25.0				
INCIPIENT			0.43	8.3	40.0				

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION 11.1.1.3 Service, 11.1.1.3.1 Standby Service, Feedwater, Turbine Lube Oil, Trans Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	
				FAILURE MODE					FAILURE RATE						
				FAILURE MODE					FAILURE RATE						
				FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES						
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES								0	11.4	150.0	17				
CATASTROPHIC								0	3.80	50.0					
Fails to Start								0	3.8	50.0					
DEGRADED								0	3.80	50.0					
INCIPIENT								0	3.80	50.0					

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CHAPTER. 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION 11.1.1.3 Service, 11.1.1.3.1 Standby Service, Fire, Motor Driven. Includes Driver	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)									
				FAILURE MODE						FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF		
								21.7	152.0	530.0	17	6.0	8.50	10.0	17										
ALL MODES				2.70	52.0	230.0																			
CATASTROPHIC				2.70	52.0	230.0																			
Fails to Start				2.70	52.0	230.0																			
DEGRADED				19.0	100.0	300.0																			
INCIPIENT																									

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement	ITEM OR EQUIPMENT DESCRIPTION 11.1.1.3 Service, 11.1.1.3.1 Standby Service, DG Oil Circul, Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
			ALL MODES							1.30	37.8	270.0	17	†	3.0			17				
			CATASTROPHIC							0	5.90	75.0										
			Fails to Start							0	5.90	75.0										
			DEGRADED							0	5.90	75.0										
			INCIPIENT							1.30	26.0	120.0										

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE															(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	REF					
	FAILURE MODE																					
	FAILURE RATE																					
FAILURE RATE															LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES																	
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES	40.6	702.0	1.27E3	17	70.8	137.0	260.0	17	2.0	77.0	300.0											
CATASTROPHIC	2.60	50.0	240.0		6.80	25.0	65.0															
Fails While Running	2.60	50.0	240.0		6.80	25.0	65.0															
Fails to Start	0	1.90	25.0		6.80	25.0	65.0															
DEGRADED					0	1.90	25.0															
INCIPIENT	38.0	650.0	1.E3		64.0	110.0	170.0															

CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.1 Positive Displacement

11.1.1.3 Service, 11.1.1.3.2 Alternating Service, Residual Heat Removal, Motor Driven Includes Driver

ITEM OR EQUIPMENT DESCRIPTION		FAILURE MODE		FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES		2.20	83.03	1.98E3											1.0 †	33.0	100.0	
CATASTROPHIC		0	8.63	200														
Fails When Running		0	8.63	200														
DEGRADED		1.10	37.2	380														
INCIPIENT		1.10	37.2	1.4E3														

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.1 Positive Displacement

11.1.1.3 Service, 11.1.1.3.3 Continuous Service

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE																		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement																		
11.1.1.3 Service, 11.1.1.3.3 Continuous Service, Turbine, Main Lube Oil, Motor Driven Includes Driver																				
ALL MODES		2.2	46.7	260	17															
CATASTROPHIC		0	4.7	62.0																
Fails While Running		0	4.7	62.0																
DEGRADED		1.10	21.0	99.0																
INCIPIENT		1.10	21.0	99.0																

CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps	SUBSECTION: 11.1.1 Positive Displacement											
ITEM OR EQUIPMENT DESCRIPTION														
11.1.1.3 Service, 11.1.1.3.3 Continuous Service, PD Charging, Motor Driven Includes Driver														
FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF	
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	779.0	1.2E3	1.98E3	17							1.0 †	33.0	100.0	17
CATASTROPHIC	2.1	42.0	200											
Fails While Running	2.1	42.0	200											
DEGRADED	57.0	170.0	380.0											
INCIPIENT	720.0	1.E3	1.4E3											

(Composite of Ref 4, 15 and 11.1.2.X)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION

FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES	0	99.9	2.61E3		0	32.70	850.0		1.0	*159.0	7.93E3					
CATASTROPHIC	0	7.07	584		0	4.73	254.0									
Fails While Running	0	7.07	584		0	4.73	254.0									
Fails to Start	0	14.7	834		0	2.12	246.0									
DEGRADED	0	84.2	1.19E3		0	25.80	350.0									
INCIPIENT																

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		5.78	7.22	12.01	4												

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CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁷ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		2.10	7.0	28.0	15							* 226.0				15

(Composite of 11.1.2.1 through 11.1.2.4)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0	106.0	2.6E3		0	32.63	850.0		1.0 †	4.75	985.0					
CATASTROPHIC		0	7.07	584.0		0	4.73	254.0		0	* 112.0	7.93E3					
	Fails While Running	0	7.07	584.0		0	4.73	254.0									
	Fails to Start	0	14.7	843.0		0	2.12	246.0									
DEGRADED		0	84.2	1.2E3		0	25.78	350.0									
INCIPIENT																	

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal
ITEM OR EQUIPMENT DESCRIPTION 11.1.2.1 Axial

FAILURE MODE	FAILURE RATE							(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS				FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH				
ALL MODES	1.17	5.73	500.0					43.0 *	127.0	814.0	

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
11.1.2.1 Axial Under 500 GPM	ALL MODES	1.17	4.68	46.80	15								432.0	* 623.0	814.0	15	

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (‡) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
11.1.2.1 Axial, 2500 - 9999 GPM	ALL MODES	12.5	50.0	500.0	15							*	26.0				15

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.2 Radial, Under 500 GPM	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
			ALL MODES	4.10	16.4	164.0	15									97.0	* 111.0	125.0	15			

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
														LOW	HIGH	REF
ALL MODES CATASTROPHIC		3.67	12.7	28.70									0	* 311.3	7.93E3	
													†	1.10		

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
11.1.2.3 Size, 11.1.2.3.1 Under 500 GPM		14.9	23.2	25.30							0	* 575.0	7.93E3			
ALL MODES CATASTROPHIC											†	0.97				

(Composite of Ref 3 and 15)
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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
11.1.2.3 Size, 11.1.2.3.1 Under 500 GPM	ALL MODES	14.9	21.30	25.60	15							0	* 575.0	7.93E3	15

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
				FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF	
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ITEM OR EQUIPMENT DESCRIPTION 11.1.2.3 Size, 11.1.2.3.1 Centrifugal, 8 GPM, 90 Ft Head 1 hp			ALL MODES	17.10			3							† 1.0			3

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.2 Centrifugal								
ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
FAILURE MODE		FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC					HIGH
11.1.2.3 Size, 11.1.2.3.1 Centrifugal, 20 GPM, 50 Ft Head, 3 hp												
ALL MODES			10.6						†	0.90		3

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.3 Size, 11.1.2.3.1 Sump, Centrifugal, 30 GPM, 25 Ft Head, 1 hp	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES					9.35				3							† 1.0				3		

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.2 Centrifugal									
ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
FAILURE MODE		FAILURE RATE											
		FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES								
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES			136.0								† 0.80		
					3								3

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
				FAILURE MODE			FAILURE RATE			FAILURE RATE			LOW	HIGH	REF					
				LOW	HIGH	REF	LOW	HIGH	REF	LOW	HIGH	REF								
			11.1.2.3 Size, 11.1.2.3.1 Centrifugal, 150 GPM, 70 Ft. Head, (Sewage Pump)																	
			ALL MODES	30.3		3											† 1.25			3

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
11.1.2.3 Size, 11.1.2.3.1 Centrifugal, 170 GPM, 173 Ft Head, 15 hp			7.84				3						† 1.10				3
ALL MODES																	

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURE MODE										LOW	REC	HIGH	REF
	FAILURES/10 ⁶ HOURS **					FAILURES/10 ³ CYCLES								
LOW	REC	HIGH	REF	REF	LOW	REC	HIGH	REF	REF	LOW	REC	HIGH	REF	
ALL MODES		68.0		3							†	0.80		3

** Calendar Hours

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CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ -HOURS					FAILURES/10 ³ -CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
11.1.2.3 Size, 11.1.2.3.1 380 GPM, 25 Ft Head, 5 hp			24.70										† 1.0				3
ALL MODES					3												

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURE MODE						FAILURE RATE								
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
11.1.2.3 Size, 11.1.2.3.2 500 - 2499 GPM, Composite		15.03	18.3	37.6									0	* 180.40	7.1E3	
ALL MODES CATASTROPHIC														† 1.25		

(Composite of Ref 3 and 15)
CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE																
					FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
																LOW	HIGH	REF			
					13.4										†	1.25				3	
ALL MODES																					

CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.2 Centrifugal							
ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	HIGH	REF	
		LOW	REC	HIGH	LOW	REC	HIGH				
11.1.2.3 Size, 11.1.2.3.2 Centrifugal, 500 - 2499 GPM		15.0	25.1	37.6	15			0	* 114.0	792.0	15
ALL MODES											

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
11.1.2.3 Size, 11.1.2.3.3 2500 - 9999 GPM		0.75	1.0	1.25	15							0	* 632.0	7.1E3	15

Note: Not Used in the Composite

CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
11.1.2.3 Size, 11.1.2.3.4 10,000 - 50,000 GPM		3.67	6.11	10.7	15							26.0	*223.0	1.1E3	15
ALL MODES															

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		14.4	19.1	28.70	15							1.0	* 362.0	3.49E3	15

(Composite of 11.1.2.4.1 through 11.1.2.4.3)

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0	180.0	2.61E3		0	32.60	850.0		1.0 †	20.49	985.0					
CATASTROPHIC		0	12.0	584		0	4.73	254.0									
Fails While Running		0	12.0	584		0	4.73	254.0									
Fails to Start		0	25.0	834		0	2.12	246									
DEGRADED		0	143.0	1.19E3		0	25.8	350									
INCIPIENT																	

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

11.1.2.4 All Service, Composite of Standby, Alternating and Continuous Service

(Composite of Ref 14 and 11.1.2.4.1.X)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES			20.0			0	14.35	850			1.0 †	10.08	531.0			
CATASTROPHIC			20.0			0	7.86	500								
Fails While Running			20.0			0	5.83									
Fails to Start						0	2.03	254								
DEGRADED						0	0.45	246								
INCIPIENT						0	6.04	350								

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURE MODE					FAILURE RATE					LOW	REC	HIGH	REF
					FAILURES/10 ⁶ HOURS **					FAILURES/10 ³ CYCLES								
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES	20.0			14		14.0					14							
CATASTROPHIC	20.0					14.0												
Does Not Operate Includes Does Not Start						10.0												
Does Not Start	20.0					4.0												

** Failures Per 10⁶ Calendar Hours

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)											
		FAILURES/10 ⁶ HOURS **					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF								
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF														
ALL MODES CATASTROPHIC			20.0				14																
Does Not Operate Includes Does Not Start			20.0				14																
Does Not Start			20.0																				
** Failures Per 10 ⁶ Calendar Hours																							

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE											(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)										
		FAILURES/10 ⁶ HOURS **						FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF							
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH											
ALL MODES CATASTROPHIC Does Not Operate Includes Does Not Start Does Not Start			4.0 4.0		14						2.5 2.5												
** Failures per 10 ⁶ Calendar Hours			4.0								0.50												

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(Composite of 11.1.2.4.1.1 through 11.1.2.4.1.6)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES CATASTROPHIC Fails to Start DEGRADED INCIPIENT												0	14.4	850.0		1.0 †	10.08	531.0	

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURE MODE						FAILURE RATE								
		FAILURES/10 ⁶ HOURS			FAILURES/10 ⁷ CYCLES			LOW			HIGH					
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
11.1.2.4 All Services, 11.1.2.4.1 Standby Service, 11.1.2.4.1.1 Fire Pump																
ALL MODES																
CATASTROPHIC																
Fails to Start																
DEGRADED																
INCIPIENT																

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.2 Centrifugal															
ITEM OR EQUIPMENT DESCRIPTION		11.1.2.4.1 Standby Service, 11.1.2.4.1.1 Fire, Diesel Driven, Includes Driver																	
FAILURE MODE	FAILURE RATE	FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		LOW	REC	HIGH	REF		LOW	REC	HIGH	REF		LOW	REC	HIGH	REF				
ALL MODES																			
CATASTROPHIC																			
Fails to Start																			
DEGRADED																			
INCIPIENT																			

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES						83.9	220.0	480.0				1.0 †	9.0	40.0		17
CATASTROPHIC						5.90	33.0	110.0								
Fails to Start						5.90	33.0	110.0								
DEGRADED						23.0	67.0	150.0								
INCIPIENT						55.0	120.0	220.0								

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SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES						62.2	118.0	260.0									
CATASTROPHIC						2.50	14.0	44.0									
Fails to Start						2.50	14.0	44.0									
DEGRADED						0.72	6.9	66.0									
INCIPIENT						59.0	97.0	150.0									

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE																				
					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					(*) OUT OF SERVICE TIME OR (\$) RESTORE (HOURS)										
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
			11.1.2.4.1 Standby Service, 11.1.2.4.1.1 Fire, Motor and Diesel Driven, Includes Driver																						
			ALL MODES							10.4	52.9	119.0	17												
			CATASTROPHIC							8.0	35.0	54.0													
			Fails to Start							8.0	35.0	54.0													
			DEGRADED							0.30	5.90	28.0													
			INCIPIENT							2.1	12.0	37.0													

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CHAPTER: 11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.2 Centrifugal										
ITEM OR EQUIPMENT DESCRIPTION		11.1.2.4.1 Standby Service, 11.1.2.4.1.1 Fire, Diesel Driven, Includes Driver												
FAILURE MODE	FAILURE RATE	FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC					HIGH	REF	
ALL MODES							113.0	324.0	850.0	17	16.0 +	21.0	32.0	17
CATASTROPHIC							110.0	260.0	480.0					
Fails to Start							110.0	260.0	480.0					
DEGRADED							0	12.0	140.0					
INCIPIENT							2.70	52.0	230.0					

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE TIME OR (\$) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF					
ALL MODES						341.0	501.0	789.0	17	1.0 †	5.0	40.0	17	
CATASTROPHIC						0	3.8	50.0						
Fails to Start						0	3.8	50.0						
DEGRADED						0.86	17.0	79.0						
INCIPIENT						340.0	480.0	660.0						

(Composite of Ref 17 and 19)

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			450.0				23.3	129.9	767.0				1.0 †	15.93	40.0		
CATASTROPHIC			450.0				0	19.60	115.5								
Fails While Running			450.0				0	19.6	115.5								
Fails to Start							0	49.40	305.2								
DEGRADED							23.30	125.0	346.4								
INCIPIENT																	

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES								
		LOW	REC	HIGH	REF		LOW	REC	HIGH	REF			LOW	REC	HIGH
ALL MODES						75.0	234.0	700.0			6.0 †	10.0	16.0		17
CATASTROPHIC						0	12.0	140.0							
Fails to Start						0	12.0	140.0							
DEGRADED						0	12.0	140.0							
Out of Spec						75.0	210.0	420.0							

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES						23.30	110.0	385.0	17			† 36.0			17
CATASTROPHIC						0	5.9	75.0							
Fails to Start						0	5.9	75.0							
DEGRADED						1.30	26.0	120.0							
INCIPIENT						22.0	78.0	190.0							

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES						261.0	447.0	769.0	17			1.0 †	7.0	40.0	17
CATASTROPHIC						0.86	17.0	79.0							
Fails to Start						0.86	17.0	79.0							
DEGRADED						140.0	230.0	370.0							
INCIPIENT						120.0	200.0	320.0							

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE RATE															
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
				FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC			HIGH	REF
ALL MODES												61.80	170.0	409.0	17	2.0 †	16.0	67.0	17
CATASTROPHIC												0.86	17.0	79.0					
Fails to start												0.86	17.0	79.0					
DEGRADED												5.90	33.0	110.0					
INCIPIENT												55.0	120.0	220.0					

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES **					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
ALL MODES			450.0				19												
CATASTROPHIC			450.0								9.60								
Fails While Running			450.0								9.60								
Fails to Start											9.60								

** One Cycle = One Start Attempt

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES **						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			450.0				19											
CATASTROPHIC			450.0															
Fails While Running			450.0															
Fails to Start																		

** One Cycle = One Start Attempt

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES						2.40	21.80	175.0				4.0 †	8.0	20.0		
CATASTROPHIC						0.63	8.44	40.0								
Fails to Start						0.63	8.44	40.0								
DEGRADED						0	1.17	25.0								
INCIPIENT						1.77	12.20	110.0								

(Composite of Ref 17)
CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

11.1.2.4.1 Standby Service, 11.1.2.4.1.3 Containment_Spray

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES						2.40	14.60	54.0										
CATASTROPHIC						1.20	6.90	22.0										
Fails to Start						1.20	6.90	22.0										
DEGRADED						0	0.79	10.0										
INCIPIENT						1.20	6.90	22.0										

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.1 Standby Service, 11.1.2.4.1.3 Containment Spray Motor Driven, Includes Driver	FAILURE RATE														
				FAILURE MODE					FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
				FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
ALL MODES											28.40	68.20	175.0	17	4.0 †	8.0	20.0	17
CATASTROPHIC											0.40	8.3	40.0					
Fails to Start											0.40	8.3	40.0					
DEGRADED											0	1.90	25.0					
INCIPIENT											28.0	58.0	110.0					

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ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURE MODE					FAILURE RATE										
		FAILURE MODE					FAILURE RATE					LOW	REC	HIGH	REF		
11.1.2.4.1 Standby Service, 11.1.2.4.1.4 Core Spray																	
ALL MODES		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
CATASTROPHIC																	
Fails to Start																	
DEGRADED																	
INCIPIENT																	

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.1 Standby Service, 11.1.2.4.1.4 Core Spray Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)												
				FAILURE MODE			FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF						
				LOW	REC	HIGH	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF												
			ALL MODES				19.20	39.30	85.0																	
			CATASTROPHIC				0.20	3.50	16.0																	
			Fails to Start				0.20	3.50	16.0																	
			DEGRADED				0	0.79	10.0																	
			INCIPIENT				19.0	35.0	59.0																	

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	11.1.2.4.1 Standby Service, 11.1.2.4.1.4 Core Spray, Motor Driven, Includes Driver													
	FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	
	FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES							2.60	8.56	29.60				17	
CATASTROPHIC							0	0.43	5.80					
Fails to Start							0	0.43	5.80					
DEGRADED							0	0.43	5.80					
INCIPIENT							2.60	7.70	18.0					

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF				
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
(Composite of Ref 17) CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal 11.1.2.4.1 Standby Services, 11.1.2.4.1.5 High Pressure, Coolant Injection																			
ALL MODES						2.80	9.56	165.0	17										
CATASTROPHIC						1.74	4.72	69.0											
Fails to Start						1.74	4.72	69.0											
DEGRADED						0.06	1.23	36.0											
INCIPIENT						1.0	3.62	60.0											

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CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)											
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES																
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	HIGH		REC	HIGH	REF								
ALL MODES CATASTROPHIC Fails to Start DEGRADED INCIPIENT										17.70	60.80	165.0											

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ² CYCLES **					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES CATASTROPHIC Fails While Running Fails to Start			220.0		19		1.50				19							

** One Cycle = One Attempt

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES			1.6E3					0	18.4	809.0			2.0 †	7.31	531.0		
CATASTROPHIC			1.6E3					0	13.1	222.0							
Fails While Running			1.6E3					0	13.1	222.0							
Fails to Start								0	9.07	195.0							
DEGRADED								0	8.69	69.0							
INCIPIENT																	

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.1 Standby Services, 11.1.2.4.1.6 HPCI Booster Turbine Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
			ALL MODES							15.0	42.40	127.0	17								
			CATASTROPHIC							0	1.70	23.0									
			Fails to Start							0	1.70	23.0									
			DEGRADED							0	1.70	23.0									
			INCIPIENT							15.0	39.0	81.0									

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES						4.80	15.60	52.0	17								
CATASTROPHIC						0	0.79	10.0									
Fails to Start						0	0.79	10.0									
DEGRADED						0	0.79	10.0									
INCIPIENT						4.8	14.0	32.0									

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
				FAILURES/10 HOURS					FAILURES/10 ³ CYCLES **					LOW	REC	HIGH	REF	
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
				11.1.2.4.1 Standby Services, 11.1.2.4.1.6 Low Pressure Injection, RHR, Motor Driven	1.6E3	1.6E3	19	11.0	11.0	19								
ALL MODES																		
CATSTROPHIC																		
Fails to Start																		

** One Cycle = One Attempt

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CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES						3.0	20.8	103.0	17			3.0 †	3.50	4.0	17
CATASTROPHIC						3.0	17.0	53.0							
Fails to Start						3.0	17.0	53.0							
DEGRADED						0	1.90	25.0							
INCIPIENT						0	1.90	25.0							

CHAPTER: 11 Driven Equipment
SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES						70.40	130.0	245.0	17	4.0	37.0	280.0	17		
CATASTROPHIC						0.43	8.3	40.0							
Fails to Start						0.43	8.3	40.0							
DEGRADED						0	1.9	25.0							
INCIPIENT						70.0	120.0	180.0							

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
				FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
			ALL MODES							1.30	37.80	270.0	17	†	60.0			17
			CATASTROPHIC							0	5.90	75.0						
			Fails to Start							0	5.90	75.0						
			DEGRADED							0	5.90	75.0						
			INCIPIENT							1.30	26.0	120.0						

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES CATASTROPHIC Fails to Start DEGRADED INCIPIENT												1.84	40.1	223.0	17			

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.1. Standby Services, 11.1.2.4.1.6 Cooling RCIC Reactor Core Turbine Driven Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES										0.39	11.20	82.0									
CATASTROPHIC										0	1.70	23.0									
Fails to Start										0	1.70	23.0									
DEGRADED										0.39	7.80	36.0									
INCIPIENT										0	1.70	23.0									

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CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.1. Standby Services, 11.1.24.1.6 Transfer Pump Motor Driven Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)											
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF				
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF										
			ALL MODES							0.05	1.48	809.0													
			CATASTROPHIC							0	0.24	38.0													
			Fails to Start							0	0.24	38.0													
			INCIPIENT							0.05	1.0	4.9													

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
					FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES													
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES										75.1	128.0	204.0												
CATASTROPHIC										9.1	21.0	41.0												
Fails to Start										9.1	21.0	41.0												
DEGRADED										45.0	69.0	100.0												
INCIPIENT										21.0	38.0	63.0												

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES										112.0	201.0	346.0	17	2.0 †	92.0	531.0	17	
CATASTROPHIC										11.0	33.0	76.0						
Fails to Start										11.0	33.0	76.0						
DEGRADED										0.43	8.3	40.0						
INCIPIENT										100.0	160.0	230.0						

(Composite of 11.1.2.4.2.1 through 11.1.2.4.2.8)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		0	215.0	4.38E3		0	52.9	500.0		1.0 †	41.45	651.0					
CATASTROPHIC		0	24.2	980		0	3.97	81.40									
Fails While Running		0	24.2	980		0	3.97	81.40									
Fails to Start		0	24.4	1.4E3		0	3.03	140.0									
DEGRADED		0	165.0	2.E3		0	46.0	279.0									
INCIPIENT																	

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
Does Not Start					14													
Loss of Function		4.0								0.50								
Does Not Continue to Run		9.0																
Does Not Operate Given a Start		20.0			14													

Note: Not Included in the Composite

RELIABILITY DATA FOR PUMPS AND DRIVERS,

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURE MODE					FAILURE RATE								
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES								
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	HIGH	REF	
ALL MODES	46.8	118.0	365.0	17	20.7	48.6	162.0								
CATASTROPHIC	0	6.3	61.9		0	1.72	16.0								
Fails While Running	0	6.3	61.9		0	1.72	16.0								
Fails to Start	0.23	6.6	53.1		0.11	2.77	26.0								
DEGRADED	46.6	105.0	250.0		20.6	44.0	120.0								
INCIPIENT															

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

11.1.2.4.2 Alternating Service, 11.1.2.4.2.1 Raw Cooling Water

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE											
					11.1.2.4.2 Alternating Service, 11.1.2.4.2.1 Raw Cooling Water Motor Driven, Includes Driver						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
					FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC
ALL MODES					46.8	91.3	198.0	17	20.7	38.7	70.1	17				
CATASTROPHIC					3.6	17.0	67.0		1.6	5.8	15.0					
Fails While Running					3.6	17.0	67.0		1.6	5.8	15.0					
Fails to Start					0.21	4.3	21.0		0.10	1.9	9.1					
DEGRADED					43.0	70.0	110.0		19.0	31.0	46.0					
INCIPIENT																

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	11.1.2.4.2 Alternating Service, 11.1.2.4.2.1 Raw Cooling Water Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
					FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES					101.0	185.0	365.0	17	46.3	82.5	162.0	17											
CATASTROPHIC					0	2.8	37.0		0	1.2	16.0												
Fails While Running					0	2.8	37.0		0	1.2	16.0												
Fails to Start					0.63	12.0	58.0		0.28	5.3	26.0												
DEGRADED					100.0	170.0	270.0		46.0	76.0	120.0												
INCIPIENT																							

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		6.8	311.5	1.4E3	17	1.30	25.7	270.0	17			† 200.0				17
CATASTROPHIC		0	31.4	390		0	4.5	75.0								
Fails While Running		0	31.4	390		0	4.5	75.0								
Fails to Start		0	49.0	390		0	3.8	75.0								
DEGRADED		6.82	231.0	620.0		1.30	17.4	120.0								
INCIPIENT																

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.2 Alternating Service, 11.1.2.4.2.2 Residual Heat Removal, Motor Driven, Includes Driver	FAILURE RATE														
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW
ALL MODES	27.4	211.0	930.0	17	1.7	11.5	57.0	17										
CATASTROPHIC	3.4	66.0	310.0		0	1.1	14.0											
Fails While Running	3.4	66.0	310.0		0	1.1	14.0											
Fails to Start	0	15.0	200.0		0	1.1	14.0											
DEGRADED	24.0	130.0	420.0		1.7	9.3	29.0											
INCIPIENT																		

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES					351.0	499.0	710.0	17	87.8	126.0	179.0	17						
CATASTROPHIC					7.4	27.0	70.0		0.83	4.7	15.0							
Fails While Running					7.4	27.0	70.0		0.83	4.7	15.0							
Fails to Start																		
DEGRADED					43.0	82.0	140.0		11.0	21.0	34.0							
INCIPIENT					300.0	390.0	500.0		76.0	100.0	130.0							

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE														
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH
			11.1.2.4.2 Alternating Service, 11.1.2.4.2.2 Residual Heat Removal, Motor Driven, Includes Driver	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES	87.7	242.0	570.0	17	7.68	21.3	50.0	17										
CATASTROPHIC	1.2	24.0	110.0		0.69	3.9	12.0											
Fails While Running	1.2	24.0	110.0															
Fails to Start					0.69	3.9	12.0											
DEGRADED	8.5	48.0	150.0		0.69	3.9	12.0											
INCIPIENT	78.0	170.0	310.0		6.3	13.50	26.0											

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES		6.80	190.0	1.4E3	17	1.30	37.8	270.0	17	1.30	37.8	270.0	17	† 200.0				17
CATASTROPHIC		0	30.0	390.0		0	5.9	75.0		0	5.9	75.0						
Fails While Running		0	30.0	390.0		0	5.9	75.0		0	5.9	75.0						
Fails to Start		0	30.0	390.0		0	5.9	75.0		0	5.9	75.0						
DEGRADED		6.8	130.0	620.0		1.30	26.0	120.0		1.30	26.0	120.0						
INCIPIENT																		

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURE MODE					FAILURE RATE							
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES							
LOW	REC	HIGH	REF	REF	LOW	REC	HIGH	REF	REF	LOW	REC	HIGH	REF	
ALL MODES		281.0	419.0	621.0	17	28.4	107.0	308.0	17					
CATASTROPHIC		7.50	27.0	71.0		0.25	10.40	29.6						
Fails While Running		7.50	27.0	71.0		0.25	10.40	29.6						
Fails to Start		230.0	310.0	410.0		0.07	7.13	189.0						
DEGRADED		43.0	82.0	140.0		28.1	89.4	89.8						
INCIPIENT														

(Composite of Ref 17)

CHAPTER: 11 Driven
Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

11.1.2.4.2 Alternating Service, 11.1.2.4.2.3 Control Rod Drive

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment		SECTION: 11.1 Pumps		SUBSECTION: 11.1.2 Centrifugal							
	11.1.2.4.2 Alternating Service, 11.1.2.4.2.3 Control Rod Drive Motor Driven, Includes Driver											
	FAILURE MODE		FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
			FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	HIGH	REF
ALL MODES						28.40	64.50	154.0	17			
CATASTROPHIC						0.36	6.9	33.0				
Fails to Start						0.36	6.9	33.0				
DEGRADED						0	1.6	21.0				
INCIPIENT						28.0	56.0	100.0				

RELIABILITY DATA FOR PUMPS AND DRIVERS,

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.2 Alternating Service, 11.1.2.4.2.3 Control Rod Drive, Motor Driven, Includes Driver	FAILURE RATE		FAILURE MODE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)							
				FAILURE RATE						FAILURE MODE			FAILURE RATE			FAILURE MODE			
				FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC
			ALL MODES	281.0	419.0	621.0	17	142.0	208.0	308.0	17								
			CATASTROPHIC	7.5	27.0	71.0		0.25	4.8	23.0									
			Fails While Running	7.50	27.0	71.0		0.25	4.8	23.0									
			Fails to Start	230.0	310.0	410.0		120.0	160.0	210.0									
			DEGRADED	43.0	82.0	140.0		22.0	43.0	75.0									
			INCIPIENT																

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0	152.0	695.0	17	0	37.5	164.0	17	3.0 †	14.0	128.0	17				
CATASTROPHIC		0	37.6	155.0		0	3.81	36.80									
Fails While Running		0	37.6	155.0		0	3.81	36.80									
Fails to Start		0	12.6	155.0		0	3.81	36.8									
DEGRADED		0	102.0	385.0		0	29.8	90.3									
INCIPIENT																	

VALVE ACTUATORS, AND VALVES

CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	REF
					FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES							
					LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF		
ALL MODES	211.0	368.0	695.0	17	51.0	86.0	164.0	17	3.0	14.0	128.0	17						
CATASTROPHIC	1.2	23.0	110.0		0	1.3	17.0											
Fails While Running	1.2	23.0	110.0		0	1.3	17.0											
Fails to Start					0	5.2	65.0											
DEGRADED					210.0	340.0	520.0		51.0	83.0	130.0							
INCIPIENT																		

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES									
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC		HIGH	REF		
ALL MODES		0	48.0	630.0	17	0	11.7	159.0	17							
CATASTROPHIC		0	16.0	210.0		0	3.9	53.0								
Fails to Start		0	16.0	210.0		0	3.9	53.0								
Fails to Start		0	16.0	210.0		0	3.90	53.0								
DEGRADED		0	16.0	210.0		0	3.90	53.0								
INCIPIENT		0	16.0	210.0		0	3.90	53.0								

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal.

ITEM OR EQUIPMENT DESCRIPTION: 11.1.2.4.2 Alternating Service, 11.1.2.4.2.5 Service Water

FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	52.9	228.0	880.0		25.9	95.70	304.0		1.0 †	24.0	651.0			
CATASTROPHIC	9.7	51.8	310.0		0.06	2.78	52.0							
Fails While Running	9.7	51.8	310.0		0.06	2.78	52.0							
Fails to Start	4.20	44.8	210.0		2.80	25.2	92.0							
DEGRADED	39.0	132.0	360.0		23.0	67.8	160.0							
INCIPIENT														

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		101.0	359.0	880.0	17	30.2	108.0	304.0	17	4.0	213.0	578.0	17				
CATASTROPHIC		33.0	120.0	310.0		0	3.9	52.0									
Fails While Running		33.0	120.0	310.0		0	3.9	52.0									
Fails to Start																	
DEGRADED		14.0	79.0	210.0		6.20	35.0	92.0									
INCIPIENT		54.0	160.0	360.0		24.0	69.0	160.0									

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.2 Alternating Service, 11.1.2.4.2.5 Service Water, Motor Driven, Includes Driver	FAILURE RATE													
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	
				FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC
ALL MODES	52.9	155.0	327.0	17	25.9	69.9	168.0	17	0.36	6.9	33.0	17					
CATASTROPHIC	9.7	48.0	92.0		0.36	6.9	33.0										
Fails While Running	9.7	48.0	92.0		0.36	6.9	33.0										
Fails to Start																	
DEGRADED	4.20	24.0	75.0		2.50	14.0	44.0										
INCIPIENT	39.0	83.0	160.0		23.0	49.0	91.0										

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		173.0	314.0	558.0	17	70.0	123.0	213.0	17	1.0 †	24.0	651.0	17				
CATASTROPHIC		10.0	38.0	98.0		0	1.3	17.0									
Fails While Running		10.0	38.0	98.0		0	1.3	17.0									
Fails to Start																	
DEGRADED		33.0	76.0	150.0		15.0	33.0	66.0									
INCIPIENT		130.0	200.0	310.0		55.0	89.0	130.0									

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURE MODE					FAILURE RATE								
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES								
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES	196.0	735.9	1.51E3	17	37.0	182.0	470.0	17	1.0	27.9	150.0	17			
CATASTROPHIC	49.0	11.8	528.0		0	2.22	25.0								
Fails While Running	49.0	11.8	528.0		0	2.22	25.0								
Fails to Start	49.0	53.0	170.5		0	15.5	68.0								
DEGRADED	98.0	671.0	812.0		37.0	164.0	377.0								
INCIPIENT															

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

11.1.2.4.2 Alternating Service, 11.1.2.4.2.6 Boron Injection

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE															
					FAILURE MODE							FAILURE RATE							(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)	
					FAILURES/10 ⁶ HOURS				FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW
11.1.2.4.2 Alternating Service, 11.1.2.4.2.6 Boron Injection, Motor Driven, Includes Driver					399.0	843.0	1.25E3	17	217.0	307.0	470.0	17	1.0	17.0	48.0	17				
ALL MODES					0	5.2	68		0	1.9	25.0									
CATASTROPHIC					0	5.2	68		0	1.9	25.0									
Fails While Running																				
Fails to Start					19.0	68.0	180.0		6.8	25.0	65.0									
DEGRADED					380.0	770.0	1.E3		210.0	280.0	380.0									
INCIPIENT																				

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
				FAILURE MODE				FAILURE RATE								LOW	REC	HIGH	REF
				11.1.2.4.2 Alternating Service, 11.1.2.4.2.6 Boron Injection, Motor Driven, Includes Driver				FAILURES/10 ⁶ HOURS				FAILURES/10 ³ CYCLES							
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES	196.0	595.0	1.51E3	17	37.0	112.0	270.0	17	6.0	127.50	150.0	17							
CATASTROPHIC	98.0	290.0	650.0		0	5.9	75.0												
Fails While Running	98.0	290.0	650.0		0	5.9	75.0												
Fails to Start	0	16.0	210.0		0	5.9	75.0												
DEGRADED	98.0	290.0	650.0		37.0	106.0	120.0												
INCIPIENT																			

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		0	134.0	630.0		0	49.5	243.0		1.0 †	11.0	48.0					
CATASTROPHIC		0	11.4	160.0		0	14.6	60.8									
Fails While Running		0	11.4	160.0		0	14.6	60.8									
Fails to Start		0	34.0	160.0		0	9.67	60.8									
DEGRADED		0	89.0	311.0		0	25.3	122.0									
INCIPIENT																	

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		0	48.0	630.0	17	0	17.7	225.0	17								
CATASTROPHIC		0	16.0	210.0		0	5.9	75.0									
Fails While Running		0	16.0	210.0		0	5.9	75.0									
Fails to Start		0	16.0	210.0		0	5.9	75.0									
DEGRADED		0	16.0	210.0		0	5.9	75.0									
INCIPIENT		0	16.0	210.0		0	5.9	75.0									

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		141.0	278.0	587.0	17	54.4	117.0	243.0	17	1.0 †	11.0	48.0	17				
CATASTROPHIC		0	5.0	67.0		3.0	17.0	53.0									
Fails While Running		0	5.0	67.0													
Fails to Start						3.0	17.0	53.0									
DEGRADED		1.0	23.0	110.0		0.40	8.0	40.0									
INCIPIENT		140.0	250.0	410.0		51.0	92.0	150.0									

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE														(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURE MODE							FAILURE RATE									
		FAILURES/10 ⁶ HOURS							FAILURES/10 ³ CYCLES									
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES		16.0	93.0	4.38E3	17	3.20	21.50	500.0	17	8.0	60.8	32.4	17					
CATASTROPHIC		0	4.96	980.0		0	3.12	110.0										
Fails While Running		0	4.96	980.0		0	3.12	110.0										
Fails to Start		0	7.01	1.4E3		0	1.59	160.0										
DEGRADED																		
INCIPIENT		16.0	80.9	2.53		3.20	16.8	230.0										

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

11.1.2.4.2 Alternating Service, 11.1.2.4.2.8 Miscellaneous Pumps

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH
ALL MODES		775.0	2.03E3	4.38E3	17	87.2	224.0	500.0	17	8.0 †	60.8	324.0	17			
CATASTROPHIC		55.0	310.0	980.0		6.20	35.0	110.0								
Fails While Running		55.0	310.0	980.0		6.20	35.0	110.0								
Fails to Start		210.0	620.0	1.4E3		24.0	69.0	160.0								
DEGRADED		510.0	1.1E3	2.E3		57.0	120.0	230.0								
INCIPIENT																

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.2 Alternating Service, 11.1.2.4.2.8 Reactor Building CCM, Motor Driven, Includes Driver	FAILURE RATE														
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW
ALL MODES	27.6	76.4	202.0	17	6.83	18.2	49.7	17										
CATASTROPHIC	0	2.4	32.0		0	0.58	7.7											
Fails While Running	0	2.4	32.0		0	0.58	7.7											
Fails to Start	0.54	11.0	50.0		0.13	2.6	12.0											
DEGRADED	27.0	63.0	120.0		6.7	15.0	30.0											
INCIPIENT																		

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal 11.1.2.4.2 Alternating Service, 11.1.2.4.2.8 Seal Water Injection to Feedwater Pump, Motor Driven, Includes Driver	ALL MODES	16.0	79.20	283.0	17	3.20	13.8	54.0	17								
CATASTROPHIC	Fails While Running	0.95	19.0	88.0		0	0.87	12.0									
DEGRADED	Fails to Start	0.95	19.0	88.0		0	0.87	12.0									
INCIPIENT		0.05	4.2	55.0		0	0.90	12.0									
		15.0	56.0	140.0		3.20	12.0	30.0									

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.2 Alternating Service, 11.1.2.4.2.8 RB Closed Cooling Water, Motor Driven, Includes Driver	FAILURE RATE												
				FAILURE MODE					FAILURE RATE					(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES	50.0	119.0	334.0	17	18.0	45.2	124.0	17	18.0	45.2	124.0	17				
CATASTROPHIC	0	4.3	57.0		0	1.6	21.0		0	1.6	21.0					
Fails While Running	0	4.3	57.0		0	1.6	21.0		0	1.6	21.0					
Fails to Start	0	4.3	57.0		0	1.6	21.0		0	1.6	21.0					
DEGRADED	50.0	110.0	230.0		18.0	42.0	82.0		18.0	42.0	82.0					
INCIPIENT																

(Composite of 11.1.2.4.3.X)

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.3 Continuous Service

FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES	12.5	180.0	2.61E3										1.0 †	26.3	985.0	
CATASTROPHIC	0.23	8.4	645.0													
Fails While Running	0.23	8.4	645.0													
DEGRADED	0.23	28.2	912.0													
INCIPIENT	12.0	143.4	1.05E3													

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.3 Continuous Service, Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)								
				FAILURE MODE					FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES				5.0		14																
Note: Not Included in the Composite of 12.1.2.4.3																						

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
ALL MODES		12.5	180.0	2.61E3								1.0 †	26.3	985.0		
CATASTROPHIC		0.23	8.4	645.0												
DEGRADED	Fails While Running	0.23	8.4	645.0												
INCIPIENT		12.0	143.7	1.05E3												

(Composite of Ref 17)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURE MODE												LOW	REC	HIGH	REF
	FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES									
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES	30.2	110.0	373.0													
CATASTROPHIC	0	5.0	39.0													
Fails While Running	0	5.0	39.0													
DEGRADED	12.0	41.0	74.0													
INCIPIENT	16.0	64.0	280.0													

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		30.2	82.0	179.0	17												
CATASTROPHIC		2.20	13.0	39.0													
Fails While Running		2.20	13.0	39.0													
DEGRADED		12.0	31.0	66.0													
INCIPIENT		16.0	38.0	74.0													

CHAPTER: 11 Driven Equipment

SECTION: 11.1 Pumps

SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURE MODE						FAILURE RATE									
	11.1.2.4.3 Continuous Service, 11.1.2.4.3.1 Condensate Booster, Motor Driven, Includes Driver						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
ALL MODES	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
CATASTROPHIC	166.0	249.0	373.0	17												
Fails While Running	0	1.0	19.0													
DEGRADED	0	1.0	19.0													
INCIPIENT	16.0	38.0	74.0													
	150.0	210.0	280.0													

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁷ CYCLES					LOW	REC	HIGH	REF		
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		30.2	82.0	179.0	17												
CATASTROPHIC		2.2	13.0	39.0													
DEGRADED	Fails While Running	2.2	13.0	39.0													
INCIPIENT		12.0	31.0	66.0													
		16.0	38.0	74.0													

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
(Composite of Ref 17) CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal 11.1.2.4.3 Continuous Service, 11.1.2.4.3.2 Steam Gen Feed		538.0	1.47E3	2.51E3									1.0 †	46.2	800.0		
ALL MODES CATASTROPHIC Fails While Running DEGRADED INCIPIENT		83.0	236.0	920.0													
		83.0	236.0	920.0													
		28.0	222.0	490.0													
		310.0	1.02E3	1.5E3													

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SECTION: 11.1 Pumps
SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		1.19E3	1.6E3	2.18E3	17									1.0 †	28.0	538.0	17
CATASTROPHIC		83.0	170.0	300.0													
Fails While Running		83.0	170.0	300.0													
DEGRADED		130.0	230.0	380.0													
INCIPIENT		980.0	1.2E3	1.5E3													

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁷ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES		538.0	1.25E3	2.51E3	17							1.0 †	97.0	800.0	17
CATASTROPHIC		200.0	470	920											
Fails While Running		200.0	470	920											
DEGRADED		28.0	160	490											
INCIPIENT		310.0	620	1.1E3											

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CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)									
	FAILURE MODE	FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF					
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES	12.5	75.5	2.61E3															1.0 †	13.2	985.0		
CATASTROPHIC	0	4.10	600																			
Fails While Running	0	4.10	600																			
DEGRADED	0	5.50	1.3E3																			
INCIPIENT	12.0	65.90	710																			

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES						LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF								
ALL MODES		594.0	1.32E3	2.61E3	17									2.0 †	12.4	40.0	17
CATASTROPHIC		64.0	230.0	600.0													
Fails While Running		64.0	230.0	600.0													
DEGRADED		420.0	780.0	1.3E3													
INCIPIENT		110.0	310.0	710.0													

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.3 Continuous Service, 11.1.2.4.3.3 Condensate, Motor Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
				FAILURE MODE		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	REC	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
			ALL MODES	298.0	543.0	870.0	17							1.0 †	65.0	985.0	17		
			CATASTROPHIC	17.0	63.0	130.0													
			Fails While Running	17.0	63.0	130.0													
			DEGRADED	41.0	100.0	190.0													
			INCIPIENT	240.0	380.0	550.0													

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
		FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES								
		LOW	REC	HIGH	REF	LOW	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES		12.5	46.90	151.0	17											
CATASTROPHIC		0.46	8.90	42.0												
Fails While Running		0.46	8.90	42.0												
DEGRADED		0	2.0	27.0												
INCIPIENT		12.0	36.0	82.0												

ITEM OR EQUIPMENT DESCRIPTION		FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURE MODE					FAILURE RATE											
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES											
CHAPTER:	SECTION:	SECTION:	SECTION:	SECTION:	SECTION:	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
(Composite of Ref 17)	11	11.1	11.1.2	11.1.2.4.3	11.1.2.4.3.4													
Driven Equipment		Pumps	Centrifugal	Reactor Feedwater														
						111.0	241.0	520.0	17						1.0 †	26.30	985.0	17
						0.46	22.1	130.0										
						0.46	22.1	130.0										
						0	5.80	140.0										
						110.0	214.0	250.0										

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)					
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES										
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF				
ALL MODES		110.5	181.0	319.0	17												
CATASTROPHIC		0.46	8.9	42.0													
Fails While Running		0.46	8.9	42.0													
DEGRADED		0	2.0	27.0													
INCIPIENT		110.0	170.0	250.0													

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.3 Continuous Service, 11.1.2.4.3.4 Reactor Feedwater, Turbine Driven, Includes Driver	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)				
				FAILURE MODE		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
			ALL MODES	231.0	359.0	520.0	17											
			CATASTROPHIC	48.0	81.0	130.0												
			Fails While Running	48.0	81.0	130.0												
			DEGRADED	53.0	88.0	140.0												
			INCIPIENT	130.0	190.0	250.0												

(No Composite At This Level)

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
	FAILURE MODE						FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF							
11.1.2.4.3 Continuous Service, 11.1.2.4.3.5 Miscellaneous Pumps																			

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES					LOW	HIGH	REF	
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
11.1.2.4.3 Continuous Service, 11.1.2.4.3.5 Service Water (BWR)	ALL MODES	0.69	1.37	4.57	7							† 30.0			7

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CHAPTER: 11 ITEM OR EQUIPMENT DESCRIPTION	11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifuga	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURE MODE					FAILURE RATE					LOW	HIGH	REF
				11.1.2.4.3 Continuous Service, 11.1.2.4.3.5 Make-Up/Charging (PMR)					FAILURES/10 ⁶ HOURS							
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	
ALL MODES	0.57	1.14	4.54	7									† 50.0			7

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	ITEM OR EQUIPMENT DESCRIPTION 11.1.2.4.3 Continuous Service, 11.1.2.4.3.5 Circulating Water, Motor Driven, Includes Driver	FAILURE RATE														
				FAILURE MODE						FAILURE RATE						(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)		
				FAILURES/10 ⁶ HOURS			FAILURES/10 ³ CYCLES			LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW
ALL MODES	18.4	48.20	131.0	17														
CATASTROPHIC	0.40	6.70	32.0															
Fails While Running	0.40	6.70	32.0															
DEGRADED	0	1.50	20.0															
INCIPIENT	18.0	40.0	79.0															

CHAPTER: 11 Driven Equipment SECTION: 11.1 Pumps SUBSECTION: 11.1.2 Centrifugal

ITEM OR EQUIPMENT DESCRIPTION	FAILURE RATE														(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
	FAILURE MODE							FAILURE RATE							LOW	REC	HIGH	REF
	FAILURE MODE							FAILURE RATE										
LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF			
ALL MODES	162.0	239.0	465.0	17	66.2	112.2	189.0	17	1.50 †	10.0	40.0	17						
CATASTROPHIC	18.0	45.0	95.0		0.21	4.2	20.0											
Fails While Running	18.0	45.0	95.0		0.21	4.2	20.0											
Fails to Start	24.0	55.0	110.0		11.0	25.0	49.0											
DEGRADED	20.0	120.0	180.0		55.0	83.0	120.0											
INCIPIENT																		

CHAPTER: 11 Driven Equipment	SECTION: 11.1 Pumps	SUBSECTION: 11.1.2 Centrifugal	FAILURE MODE	FAILURE RATE												(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
				FAILURES/10 ⁶ HOURS						FAILURES/10 ³ CYCLES **						LOW	REC	HIGH	REF			
				LOW	REC	HIGH	REF	LOW	REC	HIGH	REF											
			ALL MODES		4.70		19															
			CATASTROPHIC		4.70										2.10							
			Fails While Running		4.70										2.10							
			Fails to Start																			

** One Cycle = One Start Attempt

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ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)						
		FAILURES/10 ⁶ HOURS					FAILURES/10 ³ CYCLES **					LOW	REC	HIGH	REF			
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF									
ALL MODES			1.30															
CATASTROPHIC			1.30				19											
Fails While Running			1.30															
Fails to Start											1.0							

** One Cycle = One Start Attempt

CHAPTER: 11 Driven SECTION: 11.1 Pumps SUBSECTION: 11.1.3 Jets

ITEM OR EQUIPMENT DESCRIPTION	FAILURE MODE	FAILURE RATE										(*) OUT OF SERVICE (†) REPAIR TIME OR (\$) RESTORE (HOURS)			
		FAILURES/10 ⁶ HOURS					FAILURES/10 ⁶ CYCLES					LOW	REC	HIGH	REF
		LOW	REC	HIGH	REF	LOW	REC	HIGH	REF						
ALL MODES	Jet	0.32	1.26	4.41	15							355.0	642.0	1.3E3	15

Note: Not Included in the Composite