DERIVATION OF COMPONENT FAILURE DATA AND TREND ANALYSIS AT POINT LEPREAU GENERATING STATION

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ABSTRACT

Component failure data collection techniques have been in place at Point Lepreau Generating Station (PLGS) since first operation in 1982. Recently, statistical software packages have been developed to manipulate the data to provide functional information on component performance. The statistical package which has been developed has been in use since the latter portion of 1991. Failure data can be produced within one to two days following completion and review of the Fourth Quarter component fault assessments.

INTRODUCTION

Overview

Reliability studies of the Special Safety Systems which have been submitted to the jurisdictional authorities in support of the PLGS Operating Licence incorporate the use of failure rates to determine the unavailability contributions of specific component failures in overall system unavailability predictions. Unavailability of each component is approximated by:

$$\bar{A}=\lambda\tau \qquad \textit{where } \lambda = \textit{Failure Rate}, \quad \tau = \textit{Failure Duration}$$

The failure duration is a function of the discovery time, time to access for repair, and the actual time to repair. The reliability analysis for normally passive Special Safety Systems currently assumes that the majority of component faults will be detected during routine testing. In this scenario, the fault is assigned to have occurred at one-half the interval between the performance of the test which had last demonstrated the successful functioning of the component and the test which detected the component fault. Hence, manipulation of the testing frequencies for those components provides a means of maintaining individual unavailability contributions to within reasonable levels given the fixed failure rates. Consequently, the validity of the reliability analyses is dependant on the accuracy of the failure data which relies on competent engineering data and assessment techniques.

The failure data used in the reliability analyses for a mature power plant should be based on the experience obtained at that facility. To obtain accurate site-specific failure data requires considerable effort to develop an extensive data base and software to process the information. This paper describes the procedures required to collect individual component failure data and the software developed at PLGS to manage the information to produce failure statistics, trends analysis and an interface with the reliability studies.

Computer Configuration

A VAX/VMS mini-computer system has been the primary storage location for the engineering and fault assessment data bases and associated support code since first plant operation. For ease of access and data management, all statistical software which references these files has also been developed on the VAX computer. A computerized fault tree analysis program (CAFTA) has been purchased to perform all reliability modelling on a PC-based workstation, and, as a result, facilities must exist which permit communication and data transfer between the VAX and the micro-computer workstation.

Development of the software is done on a "DEMO" account and is tested extensively prior to conversion to the "LIVE" VAX system. The current configuration in use at PLGS is shown in Figure 1.

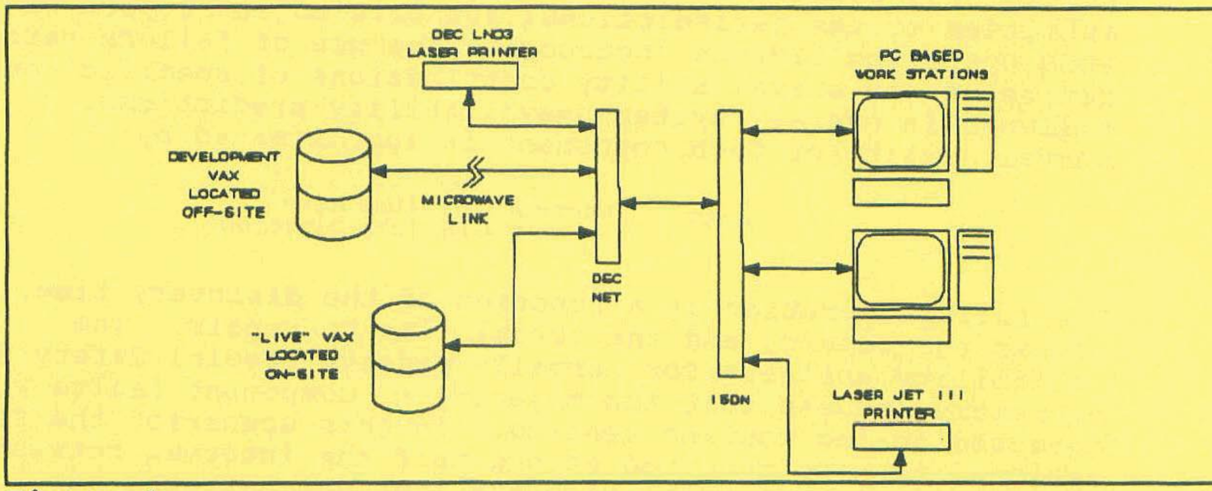

Figure 1

DATA COLLECTION

Component fault assessments are performed based on the information available to the Reliability Specialists. The information is collected from a variety of sources including Work

Permits, Work Orders, Test Results, Work Reports, Shift Supervisor Logs, Control Room Logs, and monthly Engineering Reports. The reliability specialists are located at the plant and are in direct line of distribution of all these documents as they are processed.

Generally, the information is manually collected, assessed, and entered into a data base for storage and further processing. Figure 2 illustrates a hierarchical chart of the collection and distribution process currently utilized.

DATA BASE REQUIREMENTS

The ability of statistical software to calculate failure data is dependant on comprehensive data bases which provide constructive component and component failure information.

Three primary data bases used at Point Lepreau in the development of the statistics system consist of a fault assessment data base, engineering data base (equipment library) and a fault tree component data base. These elements are illustrated in Figure 3.

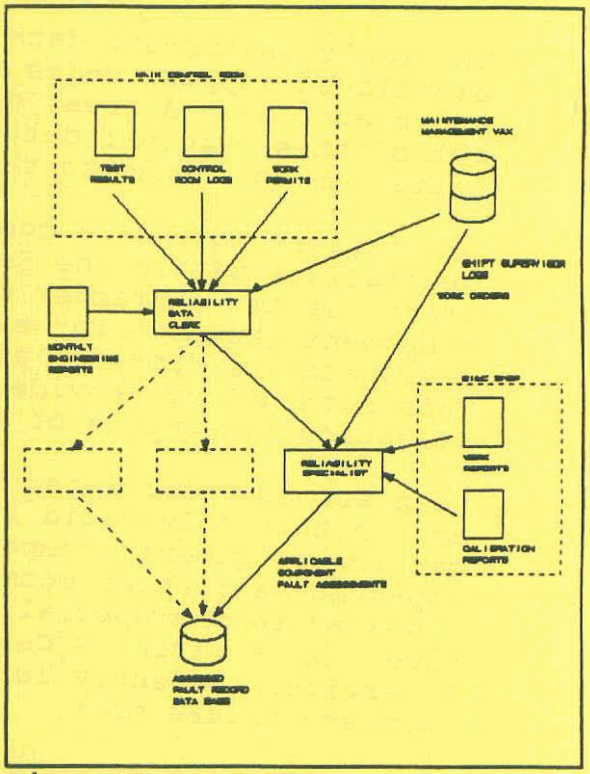

Figure 2

<u>Fault Assessment Data Base</u>

The Reliability Group has been collecting failure data on components of Special Safety Systems for over 10 years. We have over 4300 detailed Assessed Fault Records (AFR's) which have been repeatedly scrutinized for accuracy as the calibre of generated site-specific component failure data is a direct function of the quality of the specialists' fault assessments. All component faults of the Special Safety Systems are completely assessed whether or not they result in unsafe conditions of the system. The component fault assessments are typically performed on a quarterly basis in preparation for issue of the PLGS Quarterly Technical Report. Pertinent information related to each failure event is reported in this public document including the fault discovery date, the type of fault and a text description of the event.

The pertinent fault assessment items which impact on the production of failure data are listed below:

1. Affected System
2. Faulted component identification
3. Date the fault is assigned to have occurred (fault assignment date).
4. Duration required for repair.
5. Number of failures
6. Failure Mode
7. Failure Mechanism

The fault assessment data base structure and content, and the associated support codes were created solely by the Reliability Group at PLGS. A great deal of prior foresight has enabled the use of this original data base for failure data production with little or no change to the file structure.

The failure mode of a component is determined solely by the specialists within the Reliability Group. The failure modes are stored as two character codes which can be applied to all component groups. For example, a low output failure mode is designated as "LO" for all components and component subtypes*. This methodology provides a consistent approach to failure mode selection regardless of the component designation.

Help screens associated with the fault assessment data base ensure that only valid failure modes can be assessed against a particular generic component type (ie. RELAY). A series of approved validation codes stored with the help screens are compared to the specialist' entry to the fault assessment data base. If a match is detected, then the entry is accepted, otherwise, the entry is rejected and the specialist must enter another failure mode.

As the AFR help screens provide a listing of failure modes only for generic component groups, some failure modes may not apply to specific subtypes of the generic component. For example, the generic component "amplifiers" has an associated set of failure modes applicable to all amplifiers as listed below:

Erratic Output
Fails to Trip
High Output
High Voltage Power Supply Loss
Low Output
No Output
No Output Change with Changing Input

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* The term "subtype" refers to a specific component type which is a subset of the generic component group. ie. an "In-Core Amplifier" is a subtype of the generic "amplifier" component group.

Open Circuit
Setpoint High
Spurious Trip

The failure modes "Fails to Trip", "High Voltage Power Supply Loss", "Setpoint High", and "Spurious Trip" are applicable to ion chamber amplifiers, however, these modes do not apply to isolation amplifiers. Isolation amps differ in design and do not incorporate trip comparators or trip contacts. To accommodate the "exclusion" of failure modes, a data base called the "Exclusion File" has been developed to identify which failure modes of a generic component group do not apply to a specific subtype. Failure mode entries for component faults are rejected if the mode is encountered on the Exclusion File.

Engineering Data Base

To derive failure data for the components of the Special Safety Systems, a data base is required which contains every component included in these systems. The data base is comprised of every component whether or not its failure contributes to the unavailability of the system and is, therefore, also designated the "Equipment Library File".

Each component listing contains information of that component relevant to the production of failure data, including:

i) Component Identification
ii) In-Service Date
iii) Out-of-Service Date
iv) Component Characteristics

Component Identification. This is the unique identification of the component consisting of Unit, BSI (Basic Subject Index) and the Component descriptor.

In-Service Date. This is the date from which monitoring of the component began. It is used in conjunction with the out-of-service date to determine the years of service of the component.

Out-of-Service Date. This is the date at which monitoring ended for a particular component. Typically, this value is calculated as the effective date of the generation of failure data for components which are still in service. The recorded out-of-service date for components removed from service is the determining factor for calculation of the years of component service in the event that the out-of-service date precedes the effective generation date.

Component Characteristics. This description includes seven five-character fields. These fields include the; System, generic code, subtypes 1 and 2 and three further characteristics fields. These characteristics are used to categorize components into distinct functional groups.

For example, the generic code for a valve is VALVE and for a process transmitter, PTRAN. Subtype 1 can describe the construction of the component such as GATE or GLOBE for valves. Subtype 2 can represent the method of actuation of the component such as MOTOR for a motorized valve or PNDIA for a pneumatic diaphragm actuated valve.

Fault Tree Component Data Base

The Fault Tree Component data base consists of a listing of every component for each Special Safety System which is identified on the CAFTA fault tree models as a possible contribution to the unsafe failure of the system.

The information in this data base includes:

i) Component identification
ii) Type Code* identification which represents the generic code, subtype 1, subtype 2, characteristic 1 and the failure mode of the component.
iii) Failure rate of the component.
iv) Test procedure which tests the particular failure mode of the component.
v) Discovery, access and repair time for the component.

RELIABILITY UNIT STATISTICS SYSTEM

The Reliability Unit Statistics System (RUSS) has been developed utilizing the existing VAX computer configuration at Point Lepreau. As the engineering and fault assessment data bases historically have been maintained on the VAX, it was deemed logical that RUSS should be as well, to permit ease of programming and, in the interest of time, to avoid re-entry of the large amount of raw data on another, possibly incompatible, computer system.

This does not inhibit the development of the software on another system. The statistics software has been written in VAX-BASIC which allows flexible file structure and I/O functions. RUSS could be re-written in a language with similar I/O capabilities on a PC-based system. It is recommended that this PC-based system consist of computers with 80486 processors linked to a Local Area Network (LAN). 486 processors operating at a speed in excess of 25-30 MHz would be desirable due to the large amount of data processing required by RUSS. Speed limitations of lesser

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* Type codes are a five character code which CAFTA incorporates to uniquely identify groups of components and their failure mode, ie. "RLM -OC" represents a mercury wetted logic relay coil failed open circuit.

processors would likely be found to be cumbersome. A LAN would permit multiple access to the data bases (stored on a central disk drive) from a number of workstations, similar to the VAX configuration.

Hierarchical Structure

RUSS provides failure data generation capability for any selected component group or combination of component characteristics. Data is generated for lifetime failure experience and for each individual year from 1982 to the year of a specified effective date. The failure data is stored in a central file designated the "Main Statistical Data Base". Refer to Figure 3.

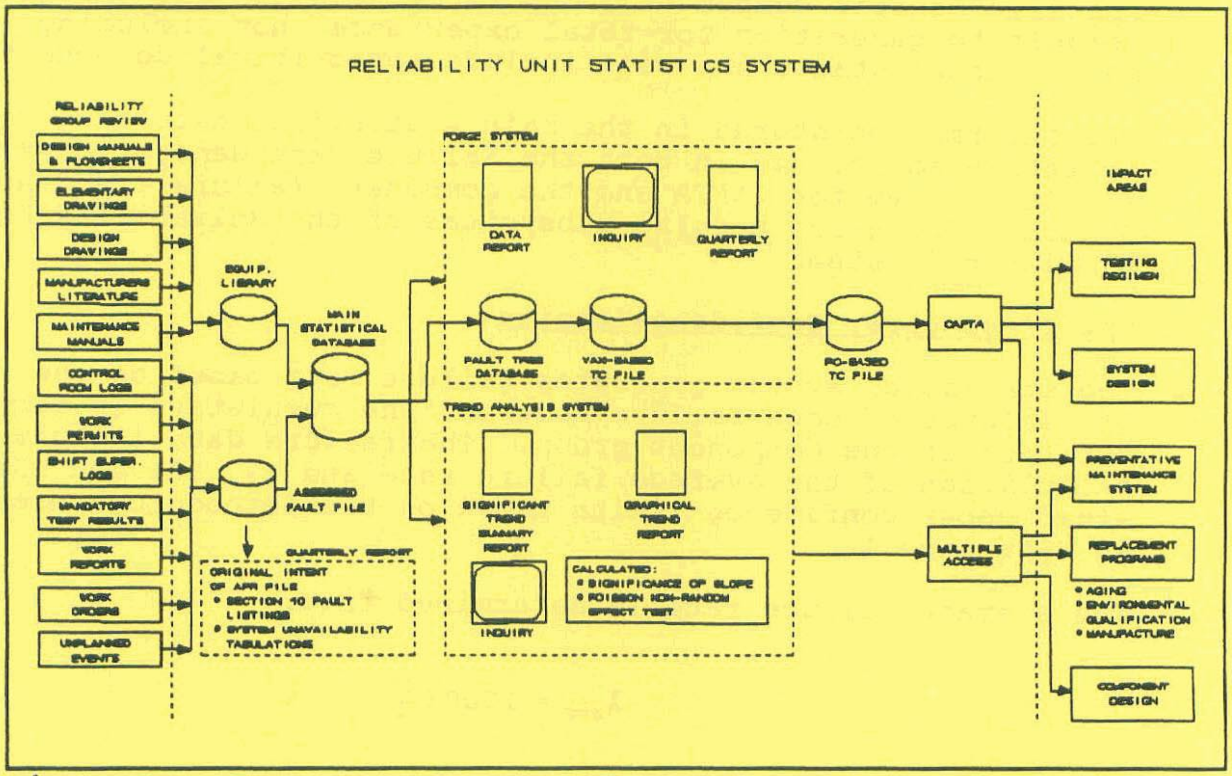

Figure 3

Component information which satisfies a user-defined selection criteria is retrieved from the engineering data base. The selection criteria consists of an entry screen whereby the user can select data generation for specific components from the engineering data base by stock code number, BSI or component characteristics. The fault assessment data base is then accessed for each individual component identification of the component group to determine if any faults have been assessed against the component. Each failure mode, the number of faults associated with that failure mode, the cumulative in-service duration, the average failure rate, the average repair time and the one-sided upper confidence limits for the entire component group is stored on the main statistical data base.

Failure data is generated for total experience or including only active components*, including or excluding maintenance outages (ie. component unavailability due to maintenance), and including or excluding non-critical components**.

It should also be mentioned that the selection criteria can be bypassed. Failure data generation can be performed for only the component groups identified on the fault tree component data base. Component groups are designated by the first five characters of the type codes which are recorded for each component. Bypass occurs when the user does not select a specific generic component group for generation and the data will default to generation for total experience, not including maintenance outages and will include non-critical components.

The information stored in the main statistical data base can then be retrieved for use in both the Failure Rate Generation*** (FoRGe) system for CAFTA and the component failure Trend Analysis System. These are modular subsystems of the Reliability Unit Statistics System.

One Sided Upper Confidence Limits

The statistics system generates failure data based on the number of failures of each failure mode and the cumulative in-service duration of the component group. The failure data includes calculation of the average failure rate and 5%, 50% and 95% one sided upper confidence limits based on the methodology described in reference 1.

The average failure rate is determined from:

$$\lambda_{avg} = 1000\left(\frac{n}{\tau}\right)$$

where n = number of observed failures of the specified mode
τ = Cumulative component in-service years

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* Active components are defined as those which have no out-of-service date.

** Critical components are those identified in the CAFTA fault tree models.

*** The FoRGe system differs in that it generates failure data for the CAFTA fault trees via a pre-selected failure mode combination technique using the raw failure data in the main statistical data base.

The confidence limits are determined from a statistical chi-squared distribution algorithm and are dependent on the degrees of freedom υ of the failures. The degrees of freedom are given by:

$$\upsilon = 2n + 2$$

The value of chi-squared distribution is tabulated for the desired confidence level up to 100 degrees of freedom.

$$\chi^2 = Table(\alpha, \nu)$$

where α = the desired confidence level (5%, 50% or 95%).

Hence, the confidence limit is determined from

$$\lambda_\alpha = 1000\left(\frac{\chi^2}{2\tau}\right)$$

In the event that the degrees of freedom exceeds 100, the chi-squared distribution is approximated by a normal distribution through the relation:

$$\lambda_\alpha = 1000\frac{\left(\frac{1}{2}(Z+\sqrt{2\nu-1})^2\right)}{2\tau}$$

where $Z = -1.645$ for 5% confidence
$Z = 0$ for 50% confidence
and $Z = +1.645$ for 95% confidence

Impact Areas

The FoRGe and trend analysis system impact on various areas of plant operation. Following annual publication, the failure data will be downloaded to the CAFTA fault trees and the model re-evaluated accordingly. The CAFTA results will identify potential improvements to component testing intervals, system design and preventative maintenance practices which contribute to predicted system unavailability. Each of these areas can be reviewed, as necessary, to ensure that the predicted values are maintained within prescribed target levels.

The trend analysis system determines the statistical significance of trends for both lifetime failure rates and for the number of failures in the reporting year. The trends give a direct indication of the effectiveness of preventative maintenance practices, replacement programs and component design. The trends may also have an indirect impact on the testing regimens and system design.

The objective of the statistics system is to detect possible divergences in component performance which will allow PLGS operating staff to formulate corrective actions to avoid system unavailability. As the failure rate generation system is intended to give lifetime failure experience based on the random occurrence of component faults, the trend analysis system will permit detection of trends which may be a result of non-random effects. Should a non-random trend be determined, then the failure data could be further rationalized based on these trend observations.

FAILURE RATE GENERATION FOR CAFTA

The FoRGe system allows manipulation of the lifetime data stored on the main statistical data base which is intended for use with CAFTA. Elements of FoRGe include a full screen inquiry, main statistical data base maintenance and report programs, fault tree component data base maintenance and reporting, maintenance of a VAX-based Type Code file, and a variety of support utilities.

To summarize the operation of the FoRGe system; Failure data is read from the main statistical data base and downloaded into the fault tree component data base for master storage. As previously indicated, the fault tree component data base contains the type codes, failure modes and failure rates for each component identified in CAFTA. The failure data may be combined with contributions from additional failure modes as determined from a combinations file.

The failure data from the fault tree component data base can then be used in conjunction with the basic event labelling scheme*, to produce a VAX-based type code file with the exact same structure as the CAFTA type code file.

The FoRGe system then provides an interface to permit data transfer from the VAX to the PC-based version of CAFTA. This interface requires that a communication package exist on both the VAX and the PC workstation. Currently, the analysts at PLGS are using SmartTerm 240 with KERMIT data transfer protocol to facilitate the data exchange.

Failure Mode Combinations

It was found desirable that a feature should exist which would allow the combination of contributions from a variety of failure modes to be applied to a single failure mode. This would permit a reduced CAFTA fault tree model as multiple basic events could be avoided, to some degree, for specific failure modes.

For example, consider the potential failure modes of a pressure transmitter. It is conceivable that the CAFTA fault tree model

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* The labelling scheme consists of a 16 character naming convention which CAFTA uses to uniquely identify basic events.

may require modelling of the Low Output, No Output and Erratic Output failures modes as contributors to system unavailability. In order to refrain from modelling three separate basic events, FoRGe will allow combination of all three into a primary mode.

The FoRGe system combines the failure contributions from a specified additive list to the primary mode as shown in Figure 4. As a result, the analyst only need model a Low Output failure mode of the pressure transmitter.

In some instances, a failure mode in the additive list may not contribute to predicted system unavailability and the analyst may not wish to combine the failure modes. In this case, a manual override exists on the fault tree component data base to prevent automatically overwriting failure rate information during the download from the main statistical data base to the fault tree component data base. Often, analysts may include the combinations, regardless, to gain an extremely conservative failure rate for the component.

Primary Failure Mode	Additive Failure Mode
Fails to Operate	Erratic Operation Fails to Open Fails to Close Fails to Reopen Fails to Reclose
Low Output	No Output No Change in Output w/ Changing Input Erratic Output
High Output	Erratic Output No Change in Output w/ Changing Input
Spurious Operation	Spuriously Closed Spuriously Opened
Fails to Open	Fails to Operate
Fails to Close	Fails to Operate
Fails to Reopen	Fails to Operate
Fails to Reclose	Fails to Operate
Spuriously Closed	Spurious Operation
Spuriously Open	Spurious Operation
Fails to Trip	NC Contacts Fail to Open NO Contacts Fail to Close Slow Operation/Response

These combinations are applied to all components, regardless of classification or any other designation. The contributions from "additive" failure modes are taken directly from Appendix A and are not individually combined prior to combination with the primary failure mode.

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Figure 4

Data Reports

The data report produced by the FoRGe system is consistent with the EI&C failure data report format shown in Reference 1. Crucial information illustrated with the report include:

Component : Generic component group
Subclass : Breakdown of the component characteristics
Failure Mode: Each individual failure mode

No. Of. Components: Total number of components encountered on the engineering data base with the same characteristics.

No. Of. Failures: Total number of failures for each failure modes that was encountered on the fault assessment data base.

Cumulative In-Service Years: Total number of years of service for the component group as determined from the in-service and out-of-service dates of each individual components.

Failure Rate: Average and one sided upper confidence limits given for 5%, 50% and 95% confidence. Failure Rates are given in failures per thousand years.

Average Repair Time: Actual average repair durations of each failure mode as recorded in the fault assessment data base.

Item: Provides a means of quick reference to the failure data given the known type code.

Effective Date: Failure data includes contributions of failures and in-service durations up to the effective date specified for each component group.

System Code: Failure data can be generated for all systems, or for selected systems.

Figure 5 illustrates a typical page from the report. Failure information is given for all relevant failure modes of the component group.

TREND ANALYSIS SYSTEM

The trend analysis system provides a facility to interactively select trend displays for component groups and failure modes on individual or all systems. The analysis system calculates, through statistical algorithms, the significance of the trends.

The trends are based on the failure data stored in the main statistical data base for individual failure modes and do not include contributions from combined failure modes, preventing a possible masking of the trend by failures of a different mode.

Significance Decisions

Two statistical techniques have been employed to determine whether or not the historical failure experience of a component is completely random in nature. These methods are the Poisson Distribution and Significance of Slope.

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Component Reliability Statistics
SITE-SPECIFIC Failure Rate Data Report
** Total Experience **

Component: Amplifier

System Code: All Systems

Sub Class	Failure Mode	No. of Components	No. of Failures	Cumulative In-Service Years	Failure Rate per 1000yr Avg. (n/T)	One Sided Conf. Limits 5%	50%	95%	Avg. Repair Time (hours)	Item
In-Core	All Modes	34	11	321.3	34.24	21.48	36.26	56.65	1.0	PLGS AMI-
	Erratic Output		1		3.11	1.11	5.54	14.77	0.0	
	High Output		6		18.68	10.22	20.70	36.88	0.5	
	Low Output		4		12.45	6.13	14.54	28.48	1.9	
	No Function Fault		0		0.00	0.16	2.16	9.32	0.0	
	No Output		0		0.00	0.16	2.16	9.32	0.0	
	No Output Change with Input		0		0.00	0.16	2.16	9.32	0.0	
	Open Circuit		0		0.00	0.16	2.16	9.32	0.0	
	Unknown		0		0.00	0.16	2.16	9.32	0.0	
							Effective:	92/01/01		
Ion Chamber	All Modes	6	21	56.7	370.40	262.81	381.86	533.55	2.8	PLCS AMC
	Erratic Output		0		0.00	0.91	12.26	52.83	0.0	
	Fails To Trip		1		17.64	6.27	31.40	83.69	0.0	
	High Output		14		246.93	163.15	258.40	386.27	3.2	
	High Voltage Power Supply Loss		0		0.00	0.91	12.26	52.83	0.0	
	Low Output		5		88.19	46.12	99.65	185.20	2.6	
	No Function Fault		1		17.64	6.27	31.40	83.69	0.0	
	No Output		0		0.00	0.91	12.26	52.83	0.0	
	No Output Change with Input		0		0.00	0.91	12.26	52.83	0.0	
	Open Circuit		0		0.00	0.91	12.26	52.83	0.0	
	Setpoint High		0		0.00	0.91	12.26	52.83	0.0	
	Spurious Trip		0		0.00	0.91	12.26	52.83	0.0	
	Unknown		0		0.00	0.91	12.26	52.83	0.0	
							Effective:	92/01/01		
Isolation	All Modes	299	109	2777.9	39.24	33.55	39.51	45.96	1.3	PLGS AMS-
	Erratic Output		4		1.44	0.71	1.68	3.29	0.7	
	High Output		48		17.28	13.72	17.51	21.80	1.6	
	Low Output		33		11.88	9.00	12.11	15.89	1.2	
	No Function Fault		0		0.00	0.02	0.25	1.08	0.0	
	No Output		23		8.28	5.26	8.51	11.74	0.8	
	No Output Change with Input		0		0.00	0.02	0.25	1.08	0.0	
	Open Circuit		1		0.36	0.13	0.64	1.71	0.0	
	Unknown		0		0.00	0.02	0.25	1.08	0.0	
							Effective:	92/01/01		

** This report does NOT include maintenance outages
** Non-Critical Components also included

Figure 5

__Poisson Distribution__. This method is utilized to compare the failure distribution with an assumed Poisson distribution. If the agreement is good, or there is no significance, then we can draw the conclusion that the distribution of failures is influenced by chance alone. If the agreement is not good, or there is a significantly low or high number of failures in the reporting year, then we can suspect that some non-random effect or definite influence may exist. For this reason, we have termed this test the "Poisson Non-Random Effect Test".

The trend analysis system uses the Poisson distribution to estimate the probability of the random occurrence of exactly *n* failures within the reporting year. If the number of experienced failures within this period are significantly greater or lower than the number predicted by Poisson distribution, then it is likely that a non-random effect is present in the data. The methodology for these calculations has been adopted from Reference 2.

The mean number of failures based on the historical failure experience of the component group is determined from:

$$\overline{x}_T = \frac{N*F_T}{N_T}$$

Where N = Number of component years of service in reporting year
F_T = Number of failure which occurred prior to the reporting period.
N_T = Number of component years of service prior to the reporting year.

This relation takes into account, components which have been placed in service and removed from service.

The probability of the actual experienced *r* failures which occurred in the reporting period is calculated from:

$$P(r) = \frac{(\overline{x}_T)^r * e^{-\overline{x}_T}}{r!}$$

The probabilities of *r* and all higher number of failures are then summed:

$$P = \sum_{n=r}^{\infty} P(n)$$

If *P* is found to be less than 20%, then the actual number of failures could be considered to be potentially significant. The potentially significant conclusion derived from this relation is rejected if it is found that the failure experience of the component is insufficient to statistically determine significance. This avoids identifying only one or two faults as significant. The rejection test is given below:

$$P = \sum_{n=r-1}^{\infty} P(n)$$

If *P* is found to be greater than 20%, then the significance decision is declined. If *P* is found to be less than 20% and the trend was potentially significant, then we draw the conclusion that a significantly high number of failures was experienced during the reporting period.

It is useful to determine if the number of failures in the reporting period are significantly low. This would give some indication as to the effectiveness of replacement programs or possibly a change of component design which has been executed to improve component performance.

This is determined from the following equation:

$$P = \sum_{n=0}^{r} P(n)$$

If P is found to be less than 20%, then the number of failures in the reporting period is considered to be significantly low.

Figure 6 illustrates a typical trend for <2" Solenoid Valves on all systems, plotted from a graphical trend report program developed by the Reliability Group. The plotting program incorporates DECgraph which was developed by Digital Equipment Corporation.

The report displays the number of failures relative to each individual operating year, the component under observation, the failure mode and the significance conclusion. Should the number of failures in the last reported year, in this case 1991, be significantly high or low, the Poisson Non-Random Effect entry reflects the conclusion. In Figure 6, the conclusion has been found to be a significantly low number of failures. This is due to a solenoid valve replacement program which was under way at PLGS during 1991.

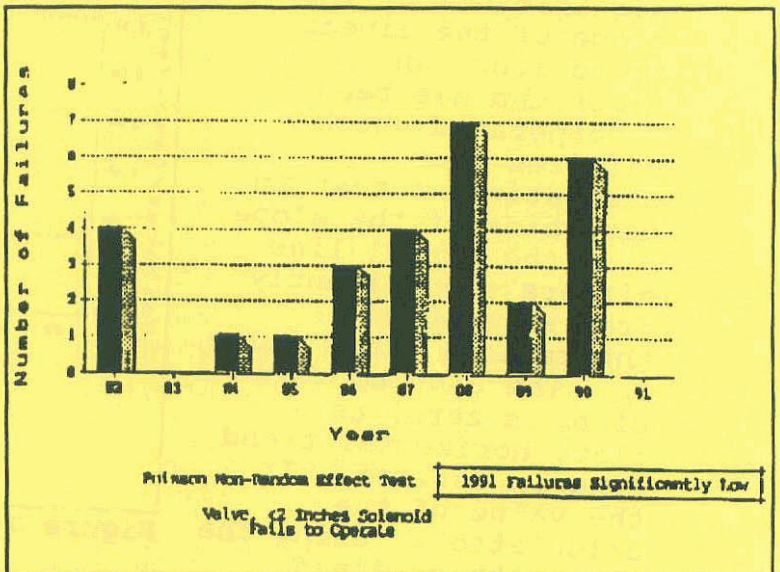

Figure 6

__Significance of Slope__. The slope of a trend line has been utilized in the trend analysis system to detect possible non-random effects such as ageing or insufficient maintenance practices on component performance. Consequently, the significance of the slope of this trend line gives an indication of the effectiveness of these preventative maintenance practices. Small perturbations in the slope of the line are expected, however, due to random component failures, but are not expected to significantly alter the trend.

The DECgraph graphical plotting package which has been incorporated into the software provides the ability to plot a linear trend line through a scatter chart of Y data points on an error-free or assigned X coordinate. It has been determined that this trend line is approximated through the method of least-squares which provides the "best" linear fit to the Y data.

Figure 7 illustrates the scatter chart and trend line for the same data points as shown in Figure 6, however, the trend analysis system approximates the least-squares line over each individual year for the number of failures per component-years of service. Thus, the trend line reflects components which may have been placed in or removed from service over the lifetime of the plant. If the trend line was calculated for "number of failures" alone, this would assume a constant number of components which is unrealistic for an operating plant.

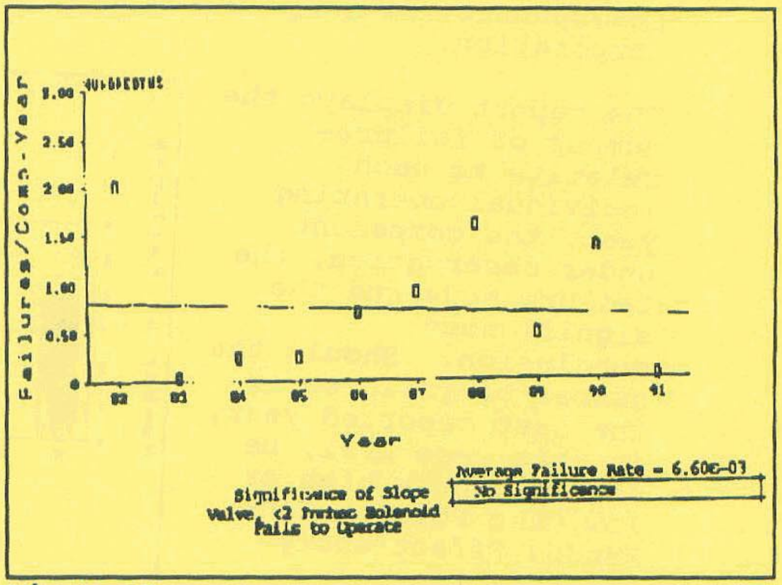

Figure 7

To determine the significance of the slope of the linear trend line, an algorithm has been incorporated which utilizes the statistical *t* test to determine if the slope *b* of the actual line differs significantly from an assumed theoretical slope value b_0. The assumed value of b_0 is zero, as a flat, horizontal trend line is desired. If the value of the calculated *t*, using the algorithm outlined below, is greater than *t* given in Table A-8 of reference 3 for a desired level of confidence, then the conclusion is drawn that the trend has a significantly increasing slope.

The methodology adopted for the trend analysis system has been extracted from reference 3.

The initial value of t is calculated from:

$$t = \frac{|b-b_0|}{S_b}$$

where S_b is the square root of the estimated variance of the slope calculated by:

$$S_b = \frac{S_{y|x}}{\sqrt{\sum (x-\overline{x})^2}}$$

And $S_{y|x}$ is the square root of the variance of the Y data points on the graph for a specified degrees of freedom as determined from:

$$S_{y|x} = \sqrt{\frac{\sum e_i^2}{\nu}}$$

Where υ = the number of years of service - 2
and ϵ = the variance of each data point from the least squares line.

At PLGS, a 5% level of confidence is employed to determine the significance of the trend line. From this level, we infer that we have 5 chances in 100 that we could have drawn an incorrect significance conclusion for the trend line, and that we are 95% confident that a significant trend exists.

CONCLUSIONS

It has been demonstrated, through operational experience, that failure data derived via the Reliability Unit Statistics System, can be generated and downloaded to the PLGS computerized fault tree models within one to two days following final review of the fourth quarter fault assessments.

The statistics system has been found to exhibit several advantages over manual data calculation;

1. Annual failure data production can be optimized by selecting only components identified in the fault trees to be generated. Additional generation can be performed at any time for other components.

2. Problems arising from adverse component experience can be pinpointed quickly. Consequently, alternate testing intervals or system configurations can be adopted which could potentially prevent system unavailability.

3. Potentially significant increases or decreases in a component failure characteristic can be readily identified and, if necessary, the mechanism removed or mitigated.

At Point Lepreau, the Reliability Group has the advantage of being located at the plant, having responsibility for all aspects of the reliability performance of the plant systems. This includes component fault evaluation, derivation of the failure data and production of the reliability analyses. We have been able to design each of these tasks to complement each other. On-site location has enabled reliability specialists to liaison directly with system engineers and operations staff to ensure precise assessment of faults. Consequently, we are confident that the failure data we produce is highly accurate.

The production of site-specific failure rates for components, the identification of failure modes and mechanism of failure, and the early identification of component failure trends enables the Reliability Group to contribute to the safe, reliable operation of the plant by showing the effectiveness of plant maintenance on possible problems.

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