PSE&G

The Energy People

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RELIABILITY SUMMARY REPORT FOR THE BAILEY 862 SOLID STATE LOGIC MODULE

ATTACHMENT 1

RELIABILITY SUMMARY REPORT FOR THE BAILEY 862 SOLID STATE LOGIC MODULE

Prepared by : Public Service Electric and Gas Co.
Nuclear Department
Engineering and Plant Betterment

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1.0 SCOPE

The scope of this summary report includes those programs which were performed through the first cycle of Hope Creek operation and are intended to demonstrate the reliability of the Bailey 862 Solid State Logic Modules (SSLM) used at Hope Creek Generating Station. These programs include an Accelerated Aging program performed by Wyle Laboratories, a SSLM failure analysis performed by Bailey Controls Co., an In-Situ Testing Feasibility Study performed by MPR Associates, and an in-house failure documentation and review program performed by PSE&G.

2.0 PURPOSE

The purpose of this report is to provide discussions of the significant aspects of the Bailey 862 Solid State Logic Module Reliability analysis programs, including resulting conclusions, justifications, and reasoning for the actions affecting the course of these programs.

3.0 DISCUSSION

Public Service Electric and Gas Co. agreed to undertake several programs intended to expeditiously determine the reliability of the Bailey 862 Solid State Logic Module, and report the results of those programs to the NRC prior to plant restart following the first refueling outage. The following discussion is intended to provide additional clarification and information which is not readily evident from the final reports of the individual programs.

3.1 SSLM FAILURE ANALYSIS

PSE&G contracted Bailey Controls Co. to perform a failure analysis on the SSLM's which malfunctioned while in-service at Hope Creek. This was accomplished by gathering all the nonconforming logic modules which were available in November of 1986 (34 SSLM's), and returning them to Bailey Controls Co. for analysis. The analysis program was broken down into a three phase program in which the module failure mode and defective components

were identified in phases 1 and 2. Phase 3 included the failure mechanism analysis on the defective components.

The results of phases 1 and 2 are included in Bailey Report QR-5106-E93-75, which provides a breakdown of the defective components for each module.

The high incidence of 4N36 Opto Isolator failures identified in the report prompted PSE&G to request further information as to the suspected cause of failures and the failure modes of the components. Bailey representatives indicated that all of the defective 4N36 Opto Isolators failed to meet Current Gain specifications, which caused the input buffer threshold levels to be out of their specified ranges. Bailey representatives were unsure of the root cause of the Opto isolator failures, although they speculated that the devices may not have been properly screened upon receipt.

The faulty Opto Isolators were subsequently analyzed in phase 3, where no physical damage to the components could be found to account for tolerance deviations.

The 4N36 Opto Isolator, ULN2001A Buffer Output driver, and 4050 Logic I/O gates experienced 84 % of the total component failures.

The Buffer Output driver and Logic I/O gates are field interfacing devices which could be directly overstressed as a result of testing or troubleshooting errors. The incidence of failures and failure mechanisms of these components supports the conclusion that many of the failures were externally induced

3.2 ACCELERATED AGING PROGRAM

PSE&G contracted Wyle Laboratories to perform an Accelerated Aging Reliability Analysis Program, where 26 SSLM's were tested after being exposed to numerous stresses intended to simulate 2, 5 and 10 year module lives.

3.2.1 BUFFER INPUT PICKUP VOLTAGE

Initial Baseline functional testing at Wyle laboratories indicated that several module input/output voltage levels did not fall within the range specified by the manufacturer. These deviations are documented in Notice of Anomoly NO. 2, and are in some cases similiar to the

inconsistencies previously experienced in the Bailey Failure Analysis program. It should be noted that Notice of Anomoly NO.2 identifies several different types of inconsistencies which will be discussed in further detail below. The input buffer pickup and dropout voltage deviations would result from the Opto Isolator out-of-tolerance condition previously discussed.

As discussed in the disposition to Notice of Anomoly No.2, PSE&G directed Wyle to test the out-of-specification Input Buffers at the elevated voltage levels (125 VDC, 118 VAC). The subsequent data indicates that the pickup voltage inaccuracy associated with the Opto Isolator tolerance is greatly reduced or eliminated in the high voltage circuits. It was decided to leave these modules in the test population to determine if the Opto Isolator characteristics drifted with age. The subject modules are repeatedly discussed throughout the test program in Notice of Anomoly No.s 2,3,4,6,7,8,9, 10,12,14,17 and 18.

Review of the final test data from the Accelerated Aging Program indicates that while the Input Buffer pickup voltage levels did increase with time, the magnitude of the drift alone, was not enough to account for the deviations which were documented in Baseline testing.

The data from both the Wyle and Bailey programs indicates that the high voltage Input Buffer pickup levels did not continuously drift, but tended to completely fail once the specification value had been marginally exceeded (approximately 3 VDC). Subsequent data from both the Bailey and Wyle programs indicates that none of the anomolous Input Buffers deviated when set to 118 VAC, and 3 deviated when set to 125 VDC. The 125 VDC deviations were either less than 3 VDC or the Input Buffer was found completed failed.

The Class 1E 862 system design at Hope Creek utilizes regulated redundant auctioneered 24 VDC supplies fed from battery-backed regulated output inverters. This design ensures that the minor variations in the low voltage Input Buffer pickup values will not have an adverse affect on the system operation. An Input Buffer pickup voltage which exceeds the 24 VDC supply would be identified in surveillances as any other failure.

3.2.2 BUFFER INPUT DROPOUT VOLTAGE

As discussed in Notice of Anomoly No. 2, four Input Buffers were found to have out-of-specification dropout voltages. The disposition to that same anomoly explains that the dropout values were relatively close to the required values, and the minor deviations would not have an adverse impact on circuit operation. The Input Buffer dropout voltage deviations are documented throughout the test program in Notice of Anomoly No.s 2, 5, and 18. Bailey Controls determined that the dropout voltage deviations were also caused by the Opto isolator tolerances.

3.2.3 LOGIC LEVEL OUTPUT VOLTAGE

As discussed in Notice of Anomoly No. 2, many of the logic and memory output "ON" voltages were found to be out-of-specification during Baseline testing.
A review of the test parameters indicated that the logic output load which was being used was overly conservative when compared to the actual Hope Creek configuration.

A plant system review was performed to identify the worst case Logic Output Load. As a result of that review, the Logic Output Test Load was changed to 4892 ohms and all logic and memory outputs were subsequently found to be in-tolerance. The worst case design load was identified to be the circuit configuration which drives two parallel Delay module inputs from a single logic output.

Notice of Anomoly No. 12 documents out-of-tolerance memory outputs on module serial number 0138. The 0.02 volt deviations (4.4 v - 4.38 v) are considered to be insignificant as the logic input threshold level of the receiving module is specified to change state at less than 3.5 volts.

3.2.4 RELATIVE HUMIDITY TESTING

Functional testing of the SSLM high relative humidity limit was complicated by several factors including misinterpretation of the manufacturers specifications, testing inadequacies, and physical difficulties in controlling relative humidity at 90 percent while ensuring the absence of condensation.

The temperature and humidity extremes specified for testing of the SSLM's (140 degrees F and 90% RH) were taken from the manufacturers Product Instruction for the device and incorporated in the PSE&G Test Specification. The temperature and humidity functional tests were combined in the test procedure developed by Wyle and reviewed by PSE&G. During performance of the humidity portion of the Baseline Functional Testing several anomolies occurred which triggered dialogue between Wyle and PSE&G. There was concern that the anomolies may have been a result of an improper test sequence, and therefore, PSE&G directed Wyle to re-attempt the test after allowing the modules to dry-out. As discussed in Notice of Anomoly No. 3, the second attempt was aborted after 6 hours and 44 minutes due to a similiar set of anomolies.

Representatives from Bailey Controls Co. were contacted and informed of the inconsistencies encountered in the test program. The Bailey representatives explained that the upper limits of temperature and relative humidity are not intended to occur simultaneously, and that the original qualification of the SSLM was performed using the nonconcurrent extremes. As a result of Bailey's clarification, PSE&G directed Wyle to modify the test procedure as discussed in the disposition to Notice of Anomoly No. 3.

Notice of Anomoly No. 17 explains that the 10 year humidity and temperature testing was, once again, incorrectly performed at the concurrent maximum limits of temperature and relative humidity. This testing deviation occurred as a result of a change in Wyle test personnel and an oversight in the procedure revision.

The Relative Humidity test procedure was found to be flawed during the Post-2 Year Humidity Operational Test. As documented in the disposition to Notice of Anomoly No. 6, opening the humidity chamber door during the humidity test caused moisture to accumulate on the test rack and specimens. The accumulation of moisture was determined to be the root cause of many of the previous anomolies experienced during Baseline and 2 year humidity testing.

The Test Procedure was modified to eliminate the need to repeatedly open the chamber door during the humidity test.

Notice of Anomoly No. 17 documents several unexplained events which occurred during the course of the 10 year humidity testing. It is our conclusion that these events were once again caused by condensation. The fact that all modules were affected by voltage dips indicates that the 9 VDC supply into the test fixture experienced transients, probably as a result of water tracking similiar to that which is documented in the Disposition to Notice Of Anomoly No. 7, for module S/N 0511.

Subsequent sections of this report explain that PSE&G is undertaking a modification which will limit the relative humidity of the SSLS environment to a maximum of 60%. This change makes the test program humidity testing extremely conservative.

3.2.5 NONCONFORMING SPECIMENS

Three of the test specimens sent to Wyle were found to be missing the modification to the solder pads of the memory toggle switches and the associated conformal coating. These modules are identified in the disposition to Notice of Anomoly No. 3, as serial numbers 0804, 0373, and 0969. These modules were found to be part of a small population which had been sent to Bailey Controls Co. for repair and modification, but were returned repaired without the modification. The total population of suspect modules has been identified and will be removed from the Hope Creek system as necessary.

Following the changes to the testing procedure, the three unmodified modules operated successfully until serial number 0373 experienced a component failure in 10-Year logic cycling which is documented in Notice of Anomoly No. 15.

3.2.6 CAPACITOR TESTING

The 2 microfarad input buffer capacitors were tested at each aging interval of the test program. Two of the capacitors were found to be out of tolerance from a total population of 416 capacitors (2 per buffer X 8 buffers per module X 26 test modules). Both of the out-of-tolerance capacitors failed such that they would not have impeded the operation of their associated input buffers. The out of tolerance capacitors are documented in Notice of Anomoly No.s 1, 7, 11 and 18.

3.2.7 FAILURE RATE

There were five module failures which occurred in the Wyle test program excluding the failure of serial number 0511 which is documented in Notice of Anomoly No. 7. This module is concluded to have failed as a result of condensation.

Table # 1 provides a breakdown of the module failures along with the failures rates for each period, in failures per million hours of service. The failure rate calculations assumed that the average module life was 18.5 months at baseline testing. This assumption is based upon the fact that approximately 20 of the 26 modules in the test population were taken directly from operation at Hope Creek with 2 years of service. The failure rate values are calculated with 2 failures at t= 18.5 months, 3 failures at t= (18.5 + 24) months, and 5 failures at t= (18.5 + 60) months. The final failure rate value is based upon 5 failures over a period of t=(18.5 + 120) months.

TABLE # 1

FAILURE/ SERIAL NO	OCCURRED	FAULTY COMPONENT	N.O.A. NO.	FAILURE RATE
NO. 1 (S/N 0799)	IN BASELINE TESTING	NOT DETERMINED	# 2	5.7
NO. 2 (S/N 0390)	IN TWO YEAR TESTING	U27 (4050) LOGIC INPUT	# 4	5.7
NO. 3 (S/N 0174)	IN POST 5 YEAR TESTING	CR18 OUTPUT LED	# 10	3.8
NO. 4 (S/N 0373)	IN TEN YEAR TESTING	U3 OPTO ISOLATOR	# 15	3.4
NO. 5 (S/N 1817)	IN POST 10 YEAR TESTING	CR13 OUTPUT LED	# 18	3.4
FIVE FAILURES TOTAL				1.9

The failure rate calculated from in-service failures at Hope Creek over the last 12 months period is equal to 1.8 failures per million hours of service (see section 3.3 for discussion of Hope Creek in-service failure rate).

It can be shown that the SSLM failure rate experienced through the Accelerated Aging Program was slightly greater than that experienced at Hope Creek. This would be expected, as all of the testing stresses that were applied were conservatively selected. It should be noted that the test program failure rate does not include the failure which was determined to have been directly caused by over-test (S/N 0511).

3.2.8 FAILED COMPONENTS

The components which failed in the Accelerated Aging Program are outlined in Table # 1. While the component failures do not differ significantly from those identified in the Bailey Failure Analysis, the data does not support any strong conclusions. The open etch failure is not consistent with previous failures experienced, supporting the conclusion that the failure was caused by condensation.

3.3 IN-HOUSE DATA ASSESSMENT PROGRAM

PSE&G performed an "in-house" data assessment program which included tracking in-service module failures on a monthly basis.

The in-service SSLM failures vs. time are graphed in Attachment # 1 for the period of March 1986 through February 1988.

As a result of the unexpected increase in failures which occurred in July 1987, PSE&G re-examined pertinent parameters in an attempt to identify the cause of the increase. The re-examination of these parameters, together with several additional months of data has led to the conclusion that the increase in failures experienced through the summer months is a result of higher average Relative Humidity in the Lower Equipment Control Room (LECR), which houses the 862 system. While Relative Humidity is maintained within the design basis of the room, and within the qualification limits

of the SSLM, the average Relative Humidity was found to increase by approximately 30% (35% to 65%) from Winter to Summer months.

The dat indicates that a lag time exists between changes in LECR Relative Humidity and changes in SSLM failure rates. To eliminate the unnecessary stresses associated with the high humidity, PSE&G has begun design of a modification which will maintain the LECR RH between 20% and 60%. Portions of the change are scheduled to be installation complete in June 1988.

3.4 OTHER 862 SSLS USERS

PSE&G contracted Bailey Controls Co. to monitor other users of the 862 Solid State Logic System and provide a report of the failure rates experienced at their facilities. The Bailey Controls Co. summary reports are provided as part of this submittal.

The information was compiled by submitting questionaires to individuals representing the following organizations which utilize the 862 SSLS.

1. Utah Power and Light Co. - misc. power plant control
2. Colorado UTE - misc. power plant control
3. Associated Electric Power - Burner Safety System
4. Inland Steel Co. - Burner Safety System

The most recent report indicates that the other users experienced 24 SSLM failures over 41,749 module-months of operation. This equates to a failure rate of 0.8 failures per million hours of service.

While this program may provide information as to the potential reliability of the system, it is our opinion that the data is less reliable than that obtained from the in-house program. The additional inaccuracy should be considered when comparing the failure rates from the two programs.

3.5 IN-SITU TESTING FEASIBILITY STUDY

PSE&G contracted MPR Associates, Inc. to perform a study of the feasibility for in-situ testing of the Bailey 862 system used at Hope Creek. The report generated as a result of that study is included as part of this submittal.

PSE&G made a conscious effort to provide as little input as possible to this effort, so as to not bias MPR's decisions in determining the most cost effective method of modifying the system to incorporate the in-situ testing feature.

The logic module costs discussed in section 3.4.1 of the MPR report are based upon a Budget Estimate provided by Bailey Controls Co. at MPR's request. It is PSE&G's position that the final cost of redesigning the logic module, providing 12 prototype and 600 production run modules, and qualifying the new device, would actually cost significantly more than the $ 1,065,000.00, estimated by Bailey Controls Co, since the cost of the replacement modules alone exceeds the MPR estimate.

Section 3.4 of the MPR report also provides time estimates for incorporation of the new device. It is our opinion that these estimates are extremely optimistic and can not consider delays associated with material availability, design conflicts resolution, resolution of qualification testing anomolies, device installation, and plant system retest.

Although MPR concludes that in-situ testing is feasible, the method proposed would require a redesign of the SSLM, effectively resulting in a new device. This method does not incorporate a self test feature on the system but redesigns the module to permit it to be partially tested without being removed from the system. This method of in-situ testing would require extensive system impact coordination when performed with the unit on line as it creates the potential of inadvertent signals capable of causing equipment operation and erroneous status information. In addition, the testable SSLM's would have no previous operating history to justify it as an improvement to system reliability.

Based upon the above discussions, PSE&G does not consider in-situ testing as a viable or cost effective method of improving plant reliability at this time.

3.6 AUTOMATED 862 SSLM BENCH TESTER

PSE&G has obtained an "Automated" 862 SSLM bench tester capable of testing all possible logic combinations with the module in its field configured state, i.e. with the FPLA on board and the staple jumpers in their field positions. The Automated tester is designed to perform the following tests:

- Input Buffer Range Test (staple jumper position determination)
- Memory Functional Test
- Logic Verification Test
- LED Operational Test
- Buffer Input Pickup and Dropout Test
- Time Response Test
- Buffered Output Leakage Test
- Fixture Operational Verification (self test)

The Automated tester data base verification has been completed, and technician training in the use of the tester is presently scheduled to begin during May 1988.

4.0 SUMMARY/CONCLUSIONS:

Based upon input from several of the programs discussed above, PSE&G has come to the conclusion that the potential exists to increase the reliability of the 862 SSLS by reducing the Relative Humidity of the environment in which the system operates. While the present failure rate is not considered to be excessive, PSE&G has begun designing modifications which will maintain the Lower Equipment Control Room Relative Humidity between 20% and 60%. It is anticipated that these modifications will reduce the average SSLM failure rate to approximately 1.1 failures per million hours of service. This estimate assumes that the failure rates experienced in the "low" humidity months can be maintained throughout the year. Refer to Attachment #1 for "in-house" SSLM failures.

This report is provided as part of a commitment which was required to demonstrate that 862 SSLM failures did not exceed 5% per year of the total population (2258 modules). Attachment #1 clearly indicates that the percent of SSLM failures over the last two year period was well below the 5% value.

As a result of the effort discussed above, we have become aware of failure rate information which we feel permits a better understanding of normal failure rates for this type of device. IEEE Standard 500-1984, "IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component and Mechanical Equipment Reliability Data for Nuclear-Power Generating Stations" provides a recommended failure rate of 1.19 failures per million hours of service for "Solid State Computation Modules" (page 721). While the Hope Creek SSLM failure rate is presently above the recommended value, the values do not differ significantly, indicating that the reliability of the 862 system is consistent with comparable solid state Nuclear equipment.

5.0 SIGNATURES

Prepared By : Michael J. Massaro
Cognizant Engineer

Date : 3-31-88

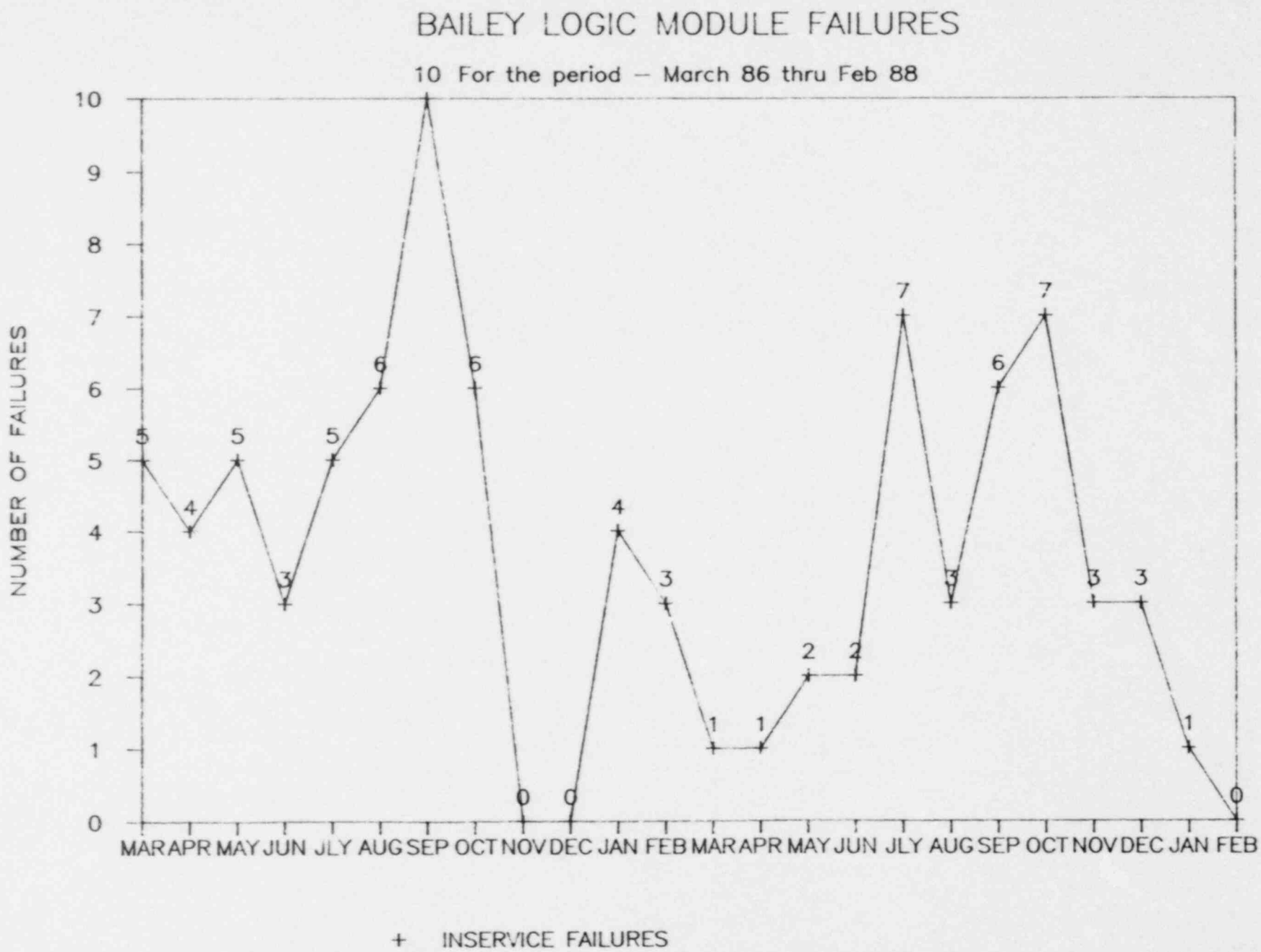
Reviewed By : Michael J. Sullivan
Hope Creek I&C Group Supervisor

Date : 3-31-88

Approved By : PPJ O'Donnell/MJS
Nuclear Electrical Engineering Manager

Date : 3-31-88

ATTACHMENT # 1



ATTACHMENT 2

COMPONENT FAILURE ANALYSIS

Attached are reports QR-5106-E93-75, "Functional Verification Report 862 Logic Module" and QR-5106-E93-75. Add-1, "Component Failure Analysis Report - 862 Logic Module" prepared by Bailey Controls Company.

Report QR-5106-E93-75 documents the results of tests performed on 34 logic modules to identify the failure mechanism of those modules. Report QR-5106-E93-75-ADD1 documents results of tests performed to identify the failure mechanisms of solid state components associated with the non-conforming modules discussed previously.

These reports satisfy PSE&G's commitment to have Bailey perform a failure analysis on failed SSLMs as documented in PSE&G letter NLR-N86142 dated October 3, 1986.