Official File

September 16, 1986

Docket Nos. 50-424, 50-425
License Nos. CPPR-108, CPPR-109

Georgia Power Company
ATTN: Mr. J. H. Miller, Jr.
President
P. O. Box 4545
Atlanta, GA 30302

Gentlemen:

The Nuclear Regulatory Commission's (NRC) Office for Analysis and Evaluation of Operational Data (AEOD) has recently completed a study on 19 newly licensed reactors. The prime objective was to characterize the trends and patterns of the events that were being experienced during the first two years of operation. The enclosed report represents a systematic review of the operating experience data bases with a focus on these "new plants."

The goal of our new plant study is to isolate specific trouble areas. Therefore, we are providing Plant Vogtle a copy of this study in order to help you identify those areas which may require close scrutiny to assure safe unit operation.

Please let us know if you have any questions.

Sincerely,

Original Signed by
Luis A. Reyes /for

Roger D. Walker, Director
Division of Reactor Projects

Enclosure:
AEOD Evaluation of New Plant
Experience

cc w/encl:
J. P. O'Reilly, Senior Vice President
Nuclear Operations
R. E. Conway, Senior Vice President &
Project Director
D. O. Foster, Vice President, Project
Support
P. D. Rice, Vice President, Project
Engineering

cc w/encl: (continued page 2)

Official File

1/1 IE01

cc w/encl: (Continued)
R. H. Pinson, Vice President, Project Construction
J. T. Beckham, Vice President & General Manager - Operations
R. A. Thomas, Vice President, Licensing
D. S. Read, General Manager, Quality Assurance
C. W. Hayes, Vogtle Quality Assurance Manager
W. C. Ramsey, Manager - Readiness Review
G. B. Bockhold, General Manager, Nuclear Operations
L. Gucwa, Manager, Nuclear Safety and Licensing
M. H. Googe, Project Construction Manager
E. D. Groover, Quality Assurance Site Manager - Construction
J. A. Bailey, Project Licensing Manager
G. F. Trowbridge, Esq., Shaw, Pittman, Potts and Trowbridge
B. W. Churchill, Esq., Shaw, Pittman, Potts and Trowbridge
E. L. Blake, Jr., Esq., Shaw, Pittman, Potts and Trowbridge
J. E. Joiner, Troutman, Sanders, Lockerman and Ashmore
W. G. Ledbetter, Commissioner, Department of Human Resources
C. H. Badger, Office of Planning and Budget
D. Kirkland, III, Counsel, Office of the Consumer's Utility Council
D. C. Teper, Georgians Against Nuclear Energy
M. B. Margulies, Esq., Chairman, Atomic Safety and Licensing Board Panel
Dr. C. H. Paris, Administrative Judge Atomic Safety and Licensing Board Panel
G. A. Linenberger, Jr., Administrative Judge Atomic Safety and Licensing Board Panel
B. P. Garde, Citizens Clinic, Director Government Accountability Project

bcc w/encl: (See page 3)

bcc w/encl:
E. Reis, OGC
W. M. Hill, IE
M. Miller, NRR
W. Brach, OGC
M. Sinkule, RII
E. Christnot, RII
NRC Resident Inspector
Document Control Desk
State of Georgia

bcc w/o encl:
K. Landis
R. Aiello

RII	RII	RII	RII
RAiello	KLandis	MSinkule	VLBrownlee
09/10/86	09/10/86	09/11/86	09/12/86

ENCLOSURE

Trends and Patterns Analysis of the Operational Experience of Newly Licensed United States Nuclear Power Reactors

August 1986

Program Technology Branch
Office for Analysis and Evaluation
of Operational Data

Principal Investigator:
Thomas R. Wolf

NOTE: This report documents the results of a study by the Office for Analysis and Evaluation of Operational Data. The findings and recommendations do not necessarily represent the position or requirements of either the responsible program office or the Nuclear Regulatory Commission.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

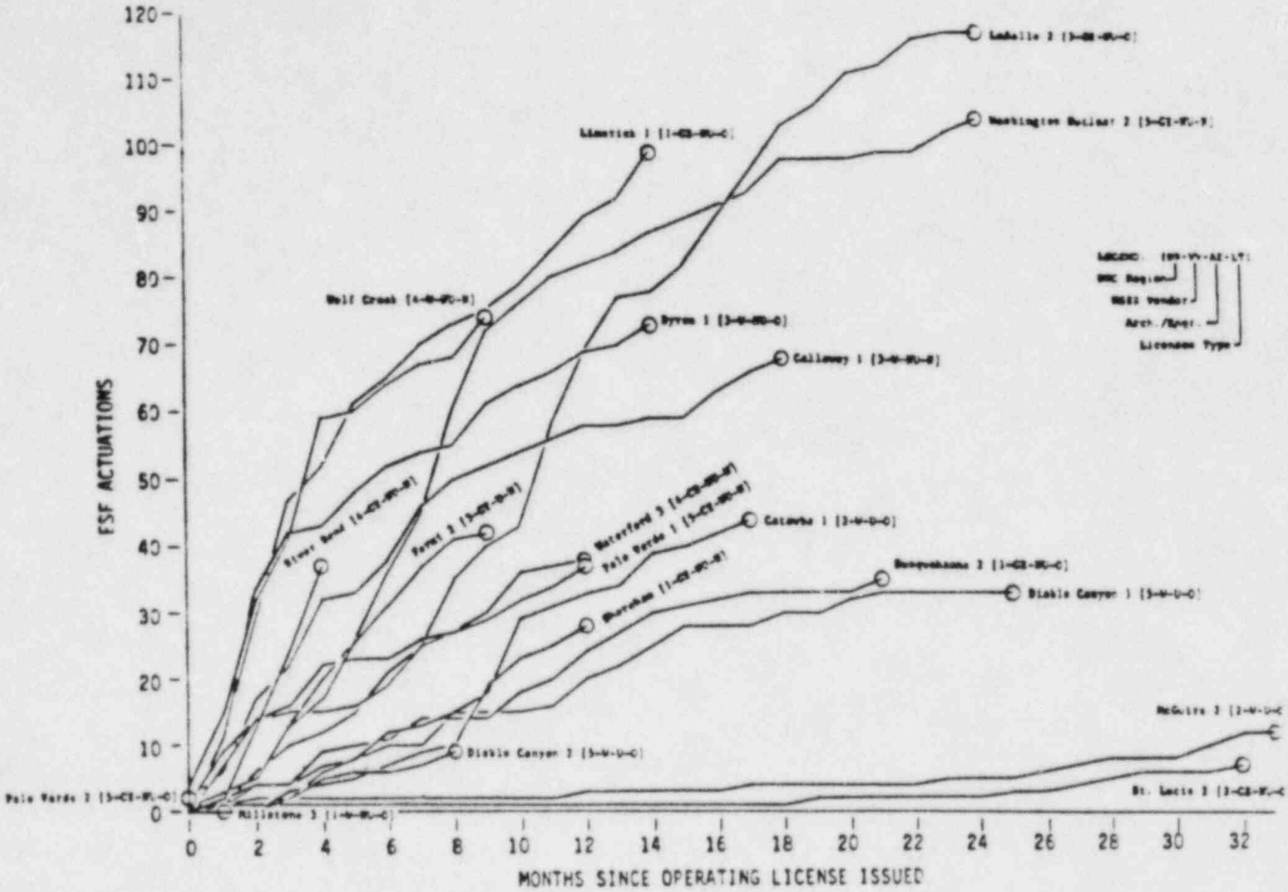
It is generally acknowledged that newly licensed reactors experience a comparatively higher frequency of reportable events during their first two years of operation than in their later years of operation. Many of these events result in challenges to safety systems or a reduction of the operating margin of the facility (e.g., violations of technical specifications). This leads to a heightened safety concern during this initial operational period. Such concern was highlighted in the 1985 Policy and Planning Guidance for the NRC as a commitment to "... continue to closely monitor the first two years of operation of new plants coming on line, particularly those of licensees who have no prior experience with nuclear plants." Program resource limitations, however, do not allow increased NRC coverage in all operating areas for all new plants. To help narrow the problem scope, the Office for Analysis and Evaluation of Operational Data (AEOD) undertook a study of the initial operational experience characteristics of 19 U. S. nuclear power reactors that received operating licenses between 1983 and 1985. These units were: Byron 1, Callaway 1, Catawba 1, Diablo Canyon 1 and 2, Fermi 2, LaSalle 2, Limerick 1, McGuire 2, Millstone 3, Palo Verde 1 and 2, River Bend, Shoreham, St. Lucie 2, Susquehanna 2, Washington Nuclear 2, Waterford 3, and Wolf Creek.

In this particular AEOD study, the prime objective was to characterize the trends and patterns of the events being experienced by a group of newly licensed reactors during their first two years of operation. From these characteristics, assessments would be made to determine those areas and units for which the greatest potential safety concerns exist. This identification could then be used to help focus further studies and resources on those areas and units which would have the greatest safety significance for newly licensed reactors.

Using only the operational experience information contained in the computerized databases associated with the Immediate Notification reports, Licensee Event Reports, and monthly operating reports, this study concentrated on: (1) reactor protection system (RPS) actuations; (2) events other than RPS actuations, such as engineered safety feature (ESF) actuations; and (3) the principal causes associated with these events. Simple tabulations and diagrams were developed and used to analyze and display this information. An example of one of the resulting figures is shown on the following page. This figure displays the cumulative sums of all of the events reported by the 19 units studied.

It was found that while each unit displayed distinct and unique initial operational characteristics, event information being received by the NRC was sufficient to indicate preliminary occurrence experience trends approximately two months after license issuance.

Based on the analyzed group data, the major types of events which were occurring during the initial period of operation of the newly licensed units



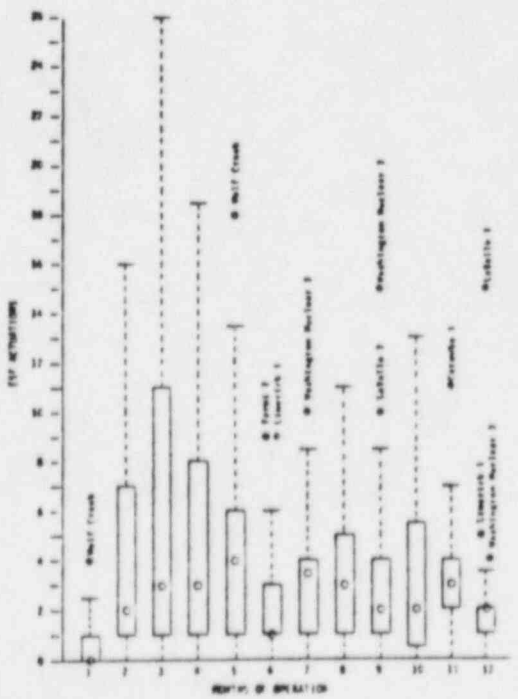
were dominated by reportable events associated with RPS and ESF actuations. These two types of events accounted for some 75 percent of all the reported occurrences being experienced at the new units studied, with RPS actuations accounting for about 25 percent and ESF actuations for about 50 percent. Upon further analysis, it was noted that the RPS actuation rates tended to remain fairly constant during the operating history studied while the ESF actuation rate tended to improve after four to eight months. Thus, an improvement in the unit performance was found for ESF actuations but not for RPS actuations. These trends, when considered with the other types of reported events (such as security events), indicated that the majority of the units experienced an overall decrease in the individual event reporting rate after approximately one year of unit operation.

Further analysis revealed that the 19 units clustered into two fairly equally divided groups, based on their associated reportable occurrence rates. Five out of the seven units whose nuclear steam supply systems were manufactured by General Electric were experiencing higher occurrence rates. Also, the units of new licensees were found to be experiencing higher numbers of events, with five of eight units being within the higher grouping and the other three units just bordering on this grouping. The lower overall reporting rate group was made up primarily of units whose nuclear steam system vendor was either Combustion Engineering or Westinghouse. The majority of the licensees in the lower rate group had previous nuclear experience. Units whose architect/engineer was also

the licensee were predominately found (i.e., four of five) in this lower event rate group.

From the study of the SCSS database, it was determined that while comparative trends on event features could be obtained, fundamental event information, such as root causes, would have to be drawn from detailed analysis of the individual LERs. AEOD is presently performing several such detailed studies of the events described in LERs for all of the operating U. S. power reactors, including the 19 units considered in this study. These individual AEOD studies include such topics as RPS and ESF actuations. Since these other AEOD studies are focusing on the fundamental types of events that are being experienced at the new units, further root cause analysis within this study was deferred.

Simple exploratory data analysis techniques were applied to the information to develop experience benchmark diagrams which would be applicable to the first 12 months of licensed unit operation. In these benchmark diagrams, known as "box-and-whisker" plots, the median value, the normally expected range (the "box"), the the area between the normally expected range and the outlier region (the "whisker"), and the outlier region were identified for each month of operation. Also identified in these diagrams were the new units which experienced a sufficient number of operational events to be classified as an outlier for the particular time period and performance measure. An example of this type of diagram follows. This particular diagram displays the box-and-whisker plots determined for the ESF actuations which occurred at the 19 units for each of the first 12 months of licensed unit operation. In this diagram, for example, the box-and-whisker plot for the second month of operation indicates that the median number of ESF actuations found to be experienced was two, while any quantity between one and seven would have been considered to be normally expected. Only if a unit had experienced more than 16 ESF actuations would that unit have been considered to be experiencing sufficient actuations to be classified as an outlier for this particular month of operation.



The basic indication given by these benchmarks was that the new operating units experienced the worst occurrence rates during the first four months after achieving a given operational milestone, such as achieving initial criticality. These rates, particularly for RPS actuations above 15 percent power and ESF actuations, were somewhat cyclical. Overall, however, a gradual decrease in the median occurrence values, a narrowing of the expected occurrence range, and a lowering of the starting value of the outlier region appeared over the first year of operation. Thus, the overall number of occurrences tended to improve with operational experience.

A comparative unit occurrence experience analysis was also conducted for just the 19 units investigated in this study. Over the first year of operation, and based solely on the indications given by the event benchmarks, the best records were demonstrated by Susquehanna 2 and St. Lucie 2. Again, based on the event benchmarks studied, the units found to have the worst experience record during their first year of operation were Callaway 1 and Byron 1. While these findings for the 19 units studied are only comparative and are not absolute, they do give indications and examples of what type of initial operational experience has been achieved for the benchmarks considered.

Conclusions

(1) Event information received by the NRC is sufficient to indicate preliminary occurrence experience trends within approximately two months following license issuance. This could allow resources to be focused fairly early in unit life on those units exhibiting relatively poor occurrence experience.

(2) The reportable events occurring at newly licensed units will predominately result in an RPS actuation, an ESF actuation, or a combination of these two actuations. However, the root causes of these occurrences were not identified. AEOD studies currently underway, which use different analysis techniques, will address root causes for these events.

(3) Over the first year of operation, and based solely on the indications given by event benchmarks developed in this study, the best occurrence experience of the 19 new units studied was recorded by Susquehanna 2 and St. Lucie 2. The units found to have the worst occurrence experience during their first year of operation were Callaway 1 and Byron 1.

Recommendations

(1) The results of this study indicate that the early operational experience (i.e., within the first two months or so after licensing) is predictive of later unit occurrence experience. Thus, the specific techniques used in this study should be considered for use in other analysis areas, such as performance indicators, to help identify those units which may require closer scrutiny to assure continued safe unit operation.

(2) The analysis conducted in this study was exploratory. Further detailed unit specific evaluation is needed to identify specific corrective measures. However, this analysis brought into focus specific items (e.g., specific units and event types) which should help to limit the resources

for such specific reviews. It is, therefore, recommended that specific evaluations be conducted of the poorest performing units identified in this study in an attempt to identify the reasons for the events that resulted in actuations of the RPS and ESF.

(3) AEOD should further monitor the initial operation of the units in this study that had been operating for less than a year. Emphasis should be placed on studying those units that displayed an initially high event frequency and appeared to be accumulating the characteristics of an outlier. In addition, and in concert with other NRC offices and regions, AEOD should further analyze the operational experience of the units identified as having the poorest operational experience and monitor all new units as they are licensed. These continued studies will be used to help identify and predict units having abnormal behavior and, thus, should indicate where additional attention and resources might be needed to help assure safe unit operation.

Trends and Patterns Analysis of the Operational Experience of Newly Licensed United States Nuclear Power Reactors

1.0 INTRODUCTION

It is generally acknowledged that newly licensed reactors experience a higher frequency of reportable events during their first two years of operation when compared to their later years of operation. Many of these events result in challenges to safety systems or a reduction of the operating margin of the facility (e.g., violations of technical specifications). This leads to a heightened safety concern during this initial operational period. One manifestation of this concern was the commitment within the 1985 NRC Policy and Planning Guidance document to "... continue to closely monitor the first two years of operation of new plants coming on line, particularly those of licensees who have no prior experience with nuclear plants."[1] Program resource limitations, however, do not allow increased NRC coverage in all operating areas for all new plants. To help narrow the problem scope, the Office for Analysis and Evaluation of Operational Data (AEOD) undertook a study of the initial operational experience characteristics of U. S. nuclear power reactors which received an initial license for power operation between 1983 and 1985.

In this particular AEOD study, the prime objective was to characterize the trends and patterns of the events being experienced by a group of newly licensed reactors during their first two years of operation. From these characteristics, assessments would be made to determine those areas and units for which the greatest potential safety concerns exist. This identification could then be used to help focus further studies and resources on those areas and units which would have the greatest safety significance for newly licensed reactors.

The data sources selected for use in this study were restricted to computerized reactor event databases such as those associated with Immediate Notifications,[2]

---

[1] U.S. Nuclear Regulatory Commission, "Policy and Planning Guidance 1985," USNRC Report NUREG-0885, Issue 4. Available for purchase from National Technical Information Service, Springfield, Virginia 22161.

[2] U.S. Nuclear Regulatory Commission, "Immediate Notification Requirements for Operating Nuclear Power Reactors," Federal Register, Vol. 48, Sept. 12, 1983, 40882.

Licensee Event Reports,[3] and monthly operating report compilations.[4] These data sources, while limited, provide basic information on the number and types of events which newly licensed power reactors are experiencing. In addition, they supply data on fundamental event characteristics (such as causes, personnel faults and equipment failures) and operational parameters (such as the number of hours a unit was critical during a given time period).

Using the information retrieved from these databases, operational event trends were determined. Additionally, exploratory data analysis tools were used to summarize the data and to define some operational benchmarks based on observed experience as a function of age. From these items, preliminary unit experience comparisons were made. At each stage of this overall analysis, study findings and conclusions were developed.

2.0 DISCUSSION

Between 1983 and 1985, initial operating licenses were granted by the NRC to 15 utilities for 19 new nuclear reactor units. The earliest of the 19 licenses was granted for the McGuire 2 unit in March 1983 and the latest for Palo Verde 2 in December 1985. The 19 units were located such that they were distributed fairly evenly within the jurisdiction of the five NRC regional offices. They included nuclear reactor systems supplied by Combustion Engineering, General Electric, and Westinghouse. Eight of the 19 units were units whose licensees were considered to have had no prior commercial nuclear plant experience. Of the 11 units whose licensees had previous operating experience, seven were located at sites where the licensee had other units already in operation. For five of the 19 units the licensee served as the architect/engineer of the project. In four of these five cases, the licensee had previous operating reactor experience. Thus, the units studied represented a good cross section of all the operating reactors within the United States. Table 1 lists the reactors studied along with some basic unit data. Additional unit data covering important operational milestones is listed in Appendix A.

---

[3] U.S. Nuclear Regulatory Commission, "Licensee Event Report System," Federal Register, Vol. 48, July 26, 1983, as amended at Vol 49, Dec. 7, 1984, 47824.

[4] U.S. Nuclear Regulatory Commission, "Licensed Operating Reactors", USNRC Report NUREG-0020. Available for purchase from National Technical Information Service, Springfield, Virginia 22161.

Table 1 U.S. Nuclear Power Reactor Units Licensed For Initial Power Operation Between 1983 and 1985

Unit Name	NRC Docket Number	NRC Region	Vendor	Initial License Date	Type of A/E	Type of Licensee
Byron 1	454	III	West	10/31/84	Non-Util	Old
Callaway 1	483	III	West	6/11/84	Non-Util	New
Catawba 1	413	I I	West	7/18/84	Utility	Old
Diablo Canyon 1	275	V	West	11/ 8/83	Utility	Old
Diablo Canyon 2	323	V	West	4/26/85	Utility	Old
Fermi 2	341	III	G E	3/30/85	Utility	New
LaSalle 2	374	III	G E	12/16/83	Non-Util	Old
Limerick 1	352	I	G E	10/26/84	Non-Util	Old
McGuire 2	370	I I	West	3/ 3/83	Utility	Old
Millstone 3	423	I	West	11/25/85	Non-Util	Old
Palo Verde 1	528	V	Comb	12/31/84	Non-Util	New
Palo Verde 2	529	V	Comb	12/ 9/85	Non-Util	Old
River Bend	458	I V	G E	8/29/85	Non-Util	New
Shoreham	322	I	G E	12/ 7/84	Non-Util	New
St. Lucie 2	389	I I	Comb	4/ 6/83	Non-Util	Old
Susquehanna 2	388	I	G E	3/23/84	Non-Util	Old
Washington Nuclear 2	397	V	G E	12/20/83	Non-Util	New
Waterford 3	382	I V	Comb	12/18/84	Non-Util	New
Wolf Creek	482	I V	West	3/11/85	Non-Util	New

Of the many sources available to the NRC which capture data that relates to the operational experience of each licensee and their associated licensed units, three were selected to be used in this AEOD investigation. These sources were: (1) Immediate Notification reports; (2) Licensee Event Reports [LERs]; and (3) monthly operating reports.

Immediate Notification Reports are telephone notifications provided by the licensee to the NRC within either one or four hours following a reportable operational event. Although these are immediate reports, the types of events occurring at each unit are generally well defined. However, the fundamental causes and other characteristics of each event may not be clear.

Licensee Event Reports are written descriptions of reportable events which must be submitted by the licensee to the NRC within 30 days of an operational occurrence. Because of the additional filing time permitted for these reports over the Immediate Notification reports, a more thorough analysis and evaluation of each event is possible. Thus, the event characteristics, such as basic causes, systems involved, component problems and personnel faults, are better defined.

Monthly Operating Reports are written accountings submitted to the NRC by each licensee which summarize basic information concerning the performance and operating status of each licensed reactor. One topic detailed in these reports

is a compilation of the number of hours that the unit was critical during each operational month.

Thus, as may be noted by these brief descriptions, the three data sources provide fairly comprehensive and comparable information on the general types of events that are being experienced at all licensed U. S. nuclear power reactors, including the newly licensed units. They also contain basic event information (such as the event causes) and operational data (such as the number of hours a unit was critical during a month). In addition, these sources are relatively easy to access and use since a computerized database is associated with each one.

2.1 Data Analysis

2.1.1 Data Collection and Basic Assumptions

To obtain the data for this investigation, the computer databases associated with each of the three chosen sources were queried for all the information which they contained on the 19 units being studied. The only query restriction was that the data to be returned must correspond to unit operation between the day on which the initial unit operating license was issued and the final day of 1985.

During this data collection process it was found that information through December 1985 could only be obtained for all 19 units from the Immediate Notification report database. This minor problem was attributed to the differences in the times associated with each report receipt, compilation and input into the different computer databases. The Licensee Event Report database yielded data only through October 1985; thus, this data covered only the 17 units which were licensed to operate prior to October 1985. Excluded from this LER data were Millstone 3 and Palo Verde 2, the two most recently licensed units included in the overall study. Similarly, data for Millstone 3, Palo Verde 2 and Shoreham was not contained in the monthly operating report database; however, the data for the other 16 units was complete through December 1985.

Because of differences in the requirements for each of the three report types used in this study, there can be some variance in the types and quantities of events reported, and thus contained in the databases used. This is especially true for the Immediate Notification and Licensee Event Report data prior to 1984, when more uniform reporting requirements became effective. However, it was assumed that over the operating history considered in this study that these variations were negligible, especially since only the two earliest licensed units in this study (McGuire 2 and St. Lucie 2) were operational for more than one or two months of 1983.

An additional assumption was made that the event information in the databases were generally compatible. Thus, the findings from the study of the event information in one database could be applied to the information obtained from a different database. This permitted, for example, the assumption that occurrence factors such as causes found in one database were indicative of the causes of the events found in another database.

2.1.2 Immediate Notification Reports

Within the Immediate Notification database, several basic categories of events are captured. These categories include: (1) reactor protection system [RPS] actuations; (2) engineered safety feature [ESF] actuations; (3) limiting conditions for operation [LCO]; (4) security; and (5) miscellaneous conditions which were reportable but could not be classified into one of the other categories. From the study of the information contained in this database on the 19 units being analyzed, it was found that approximately 25 percent of all the event data captured was associated with an actuation of the RPS. These actuations were at any power level and may or may not have involved control rod movement. Events involving ESF actuations were the other major category, accounting for slightly less than one-half of all the events being reported by each of the 19 units. The remaining event information was divided fairly equally between the remaining Immediate Notification database categories.

RPS Actuations For all reported RPS actuations, the units tended to group around two average monthly actuation frequencies of either 1.0 or 2.5. These rates and the units that were clustered around each of these rates remained constant with increasing operational experience. It was found that seven of the 19 units studied experienced the higher RPS actuation rates: Byron 1, Callaway 1, Fermi 2, River Bend, Washington Nuclear 2, Waterford 3, and Wolf Creek. The prime characteristics of these higher frequency units were that they were: (1) units of new licensees (i.e., the first nuclear unit for the operating utilities), and (2) units for which the licensee did not serve as the architect/engineer. Figure 1 graphically presents the cumulative number of RPS events reported by each of the 19 units as a function of the months since the units were issued their initial operating license.

ESF Actuations Engineered safety feature actuations, unlike the RPS rates, showed no apparent clustering or grouping about any particular actuation frequency. Each unit had its own ESF actuation rate, with two units (McGuire 2 and St. Lucie 2) experiencing exceptionally low rates. In general, the ESF actuation rate at each unit seemed to decrease after approximately four to eight months of operation. The only readily distinguishable unit traits were: (1) five of the seven units whose nuclear steam system vendor was General Electric were experiencing high ESF actuation rates, and (2) units experiencing the fewest ESF actuations were ones for which the licensee also served as the architect/engineer. Figure 2 shows the cumulative number of ESF events reported and contained in the Immediate Notification database for each of the 19 newly licensed reactors. These counts are plotted as a function of the months since the initial operating licenses were issued to these units.

LCO There is no uniform requirement to report events which would be classified as limiting conditions for operation, especially after the adoption of the revised reporting rules in 1984. Thus, LCO events were not considered in this analysis.

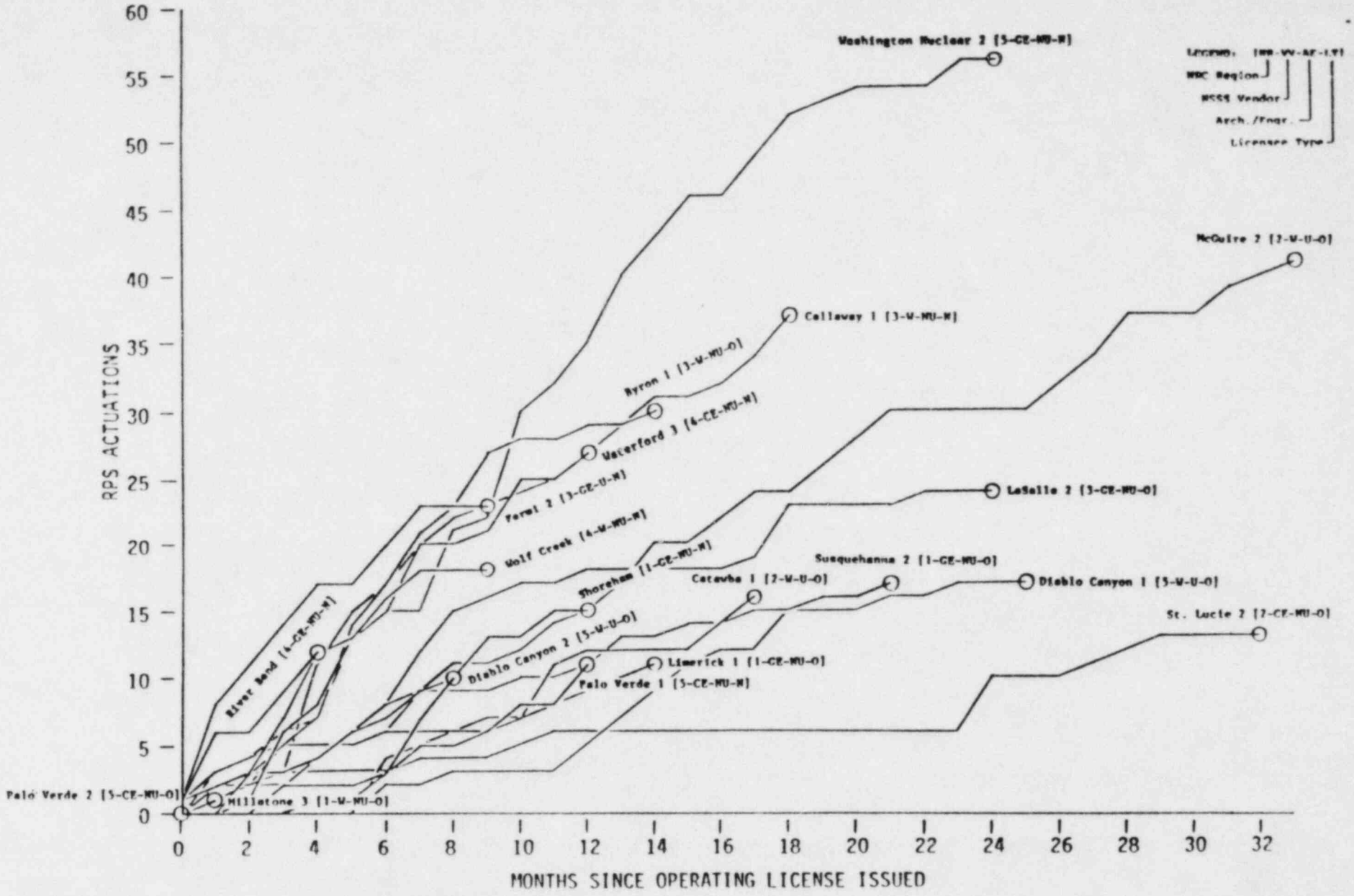


Figure 1 Cumulative Total Of RPS Event Reports

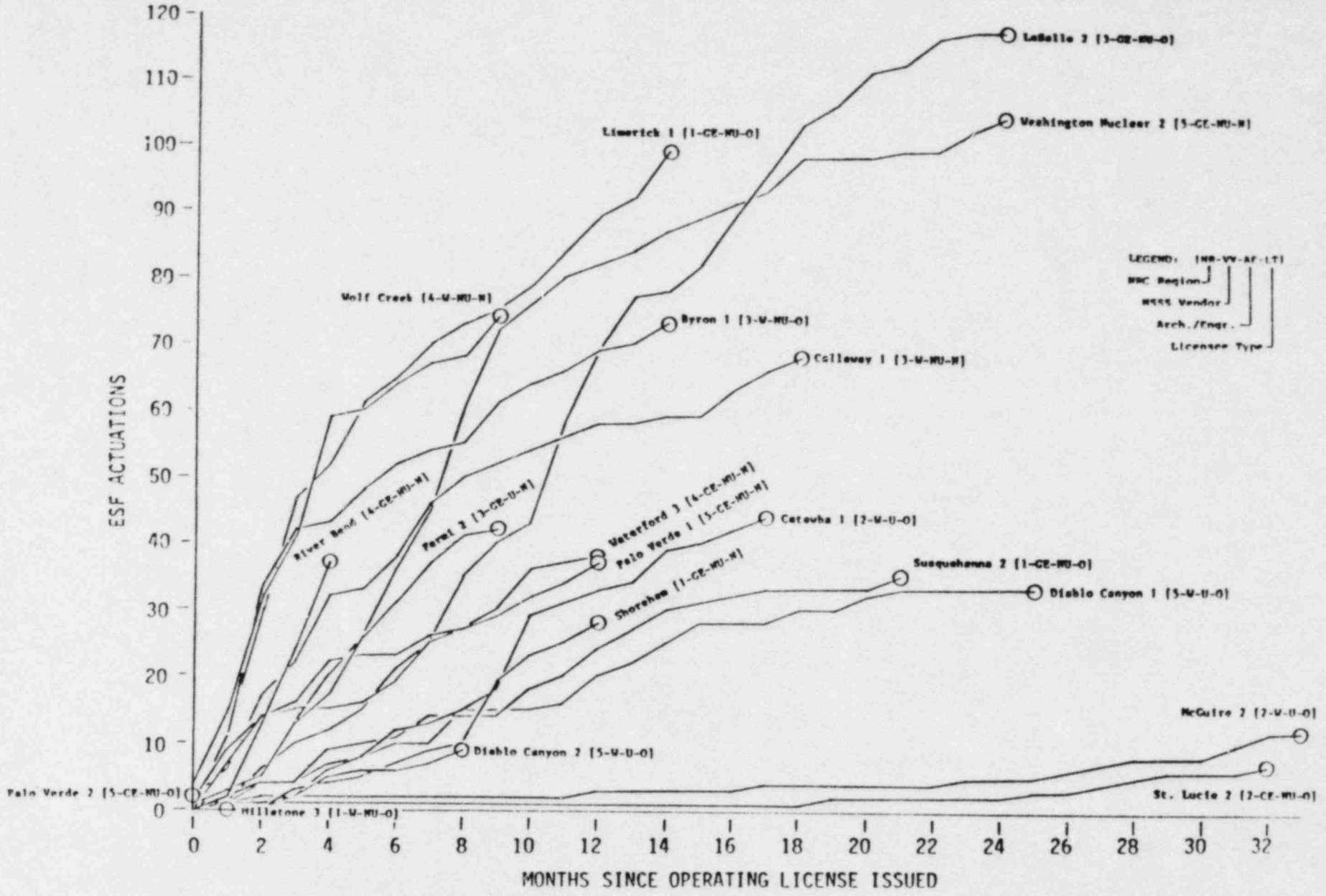


Figure 2 Cumulative Total Of ESF Event Reports

Security Few units reported numerous security events, averaging less than one event every two months. Of the units experiencing higher numbers of reportable security events, some showed high rates from the beginning of operation (these being: Byron 1, Callaway 1, Limerick 1, and River Bend); but, except for Callaway 1, this higher reporting level decreased to the overall average rate after some two to four months of operation. Three other units (Fermi 2, LaSalle 2, and Wolf Creek) also experienced above average report rates but these rates did not appear until six to ten months after the issuance of an operating license. Because of the nature of security reporting, few event details are available from the database and, thus, identification of specific security report types which could be driving some of the higher reporting rates were not determined. Overall, however, the type of unit, its location, or licensee type did not appear to affect the number of security events being reported. Figure 3 illustrates the cumulative number of security reports captured in the Immediate Notification database for the new units studied.

Miscellaneous Included in the miscellaneous category were reports of inoperative Emergency Notification Systems, events which indicated possible serious degradation in a principal safety barrier (such as local leak rate test failures), natural and external conditions that posed an actual threat to the safety of the unit (such as earthquakes, fires, and hurricanes), radioactive releases above permissible limits, discovery of unanalyzed design conditions, and occurrences or conditions that alone could have prevented the fulfillment of a principal safety function (such as the removal of residual heat). Also included in the Immediate Notification database within this miscellaneous category were voluntary reports. For this study, these voluntary reports were excluded so as not to penalize those units that issued such information.

Except for one particular unit (LaSalle 2), no distinguishing unit characteristics or report trends were noted. Even in the case of LaSalle 2, no specific event appeared to be causing the higher number of cumulative reports. The overall average frequency for the reporting of events which were classified as miscellaneous was about once per operating month. A display of the cumulative number of miscellaneous reports issued by the new units studied is given in Figure 4.

Overall As shown in Figure 5, combining all of the event categories yielded certain overall characteristics and trends. Based on the monthly frequency of total reporting, the units clustered into two fairly equally divided groups of (1) units experiencing more than eight reportable events per month and (2) units averaging approximately three reportable events per month. These event occurrence rates began to become apparent within approximately two months after the issuance of an operating license. The units in the higher rate grouping tended to continue to show the higher occurrence rate for approximately the first year of operation. After the first year of operation, all of the units in this study with that much operational experience were averaging three reportable events per month.

For the overall higher reporting group, five out of the seven units which had nuclear steam supply systems manufactured by General Electric were in this group. Also, the units of new licensees were found to be experiencing high

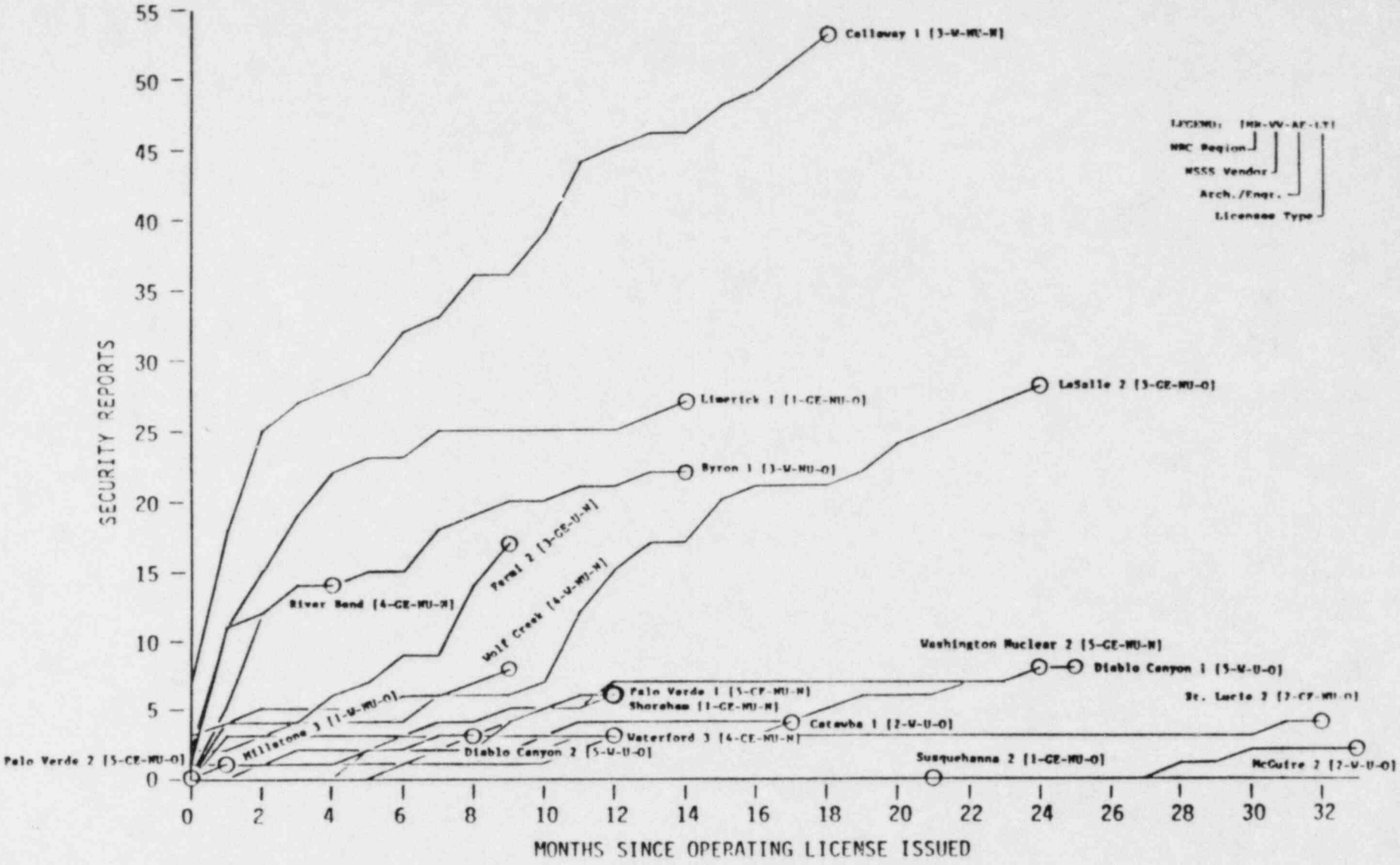


Figure 3 Cumulative Total Of Security Event Reports

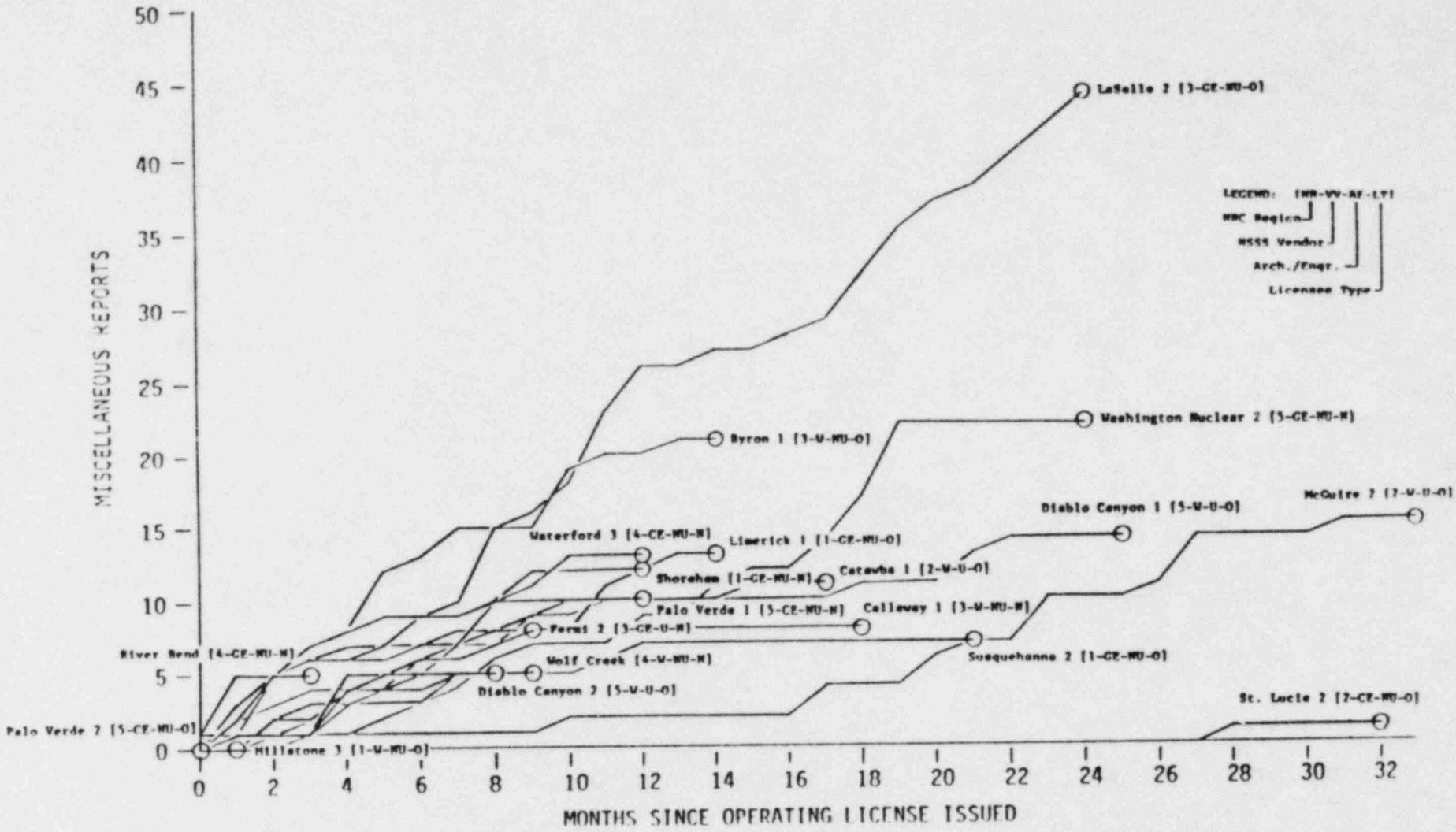


Figure 4 Cumulative Total Of Miscellaneous Event Reports

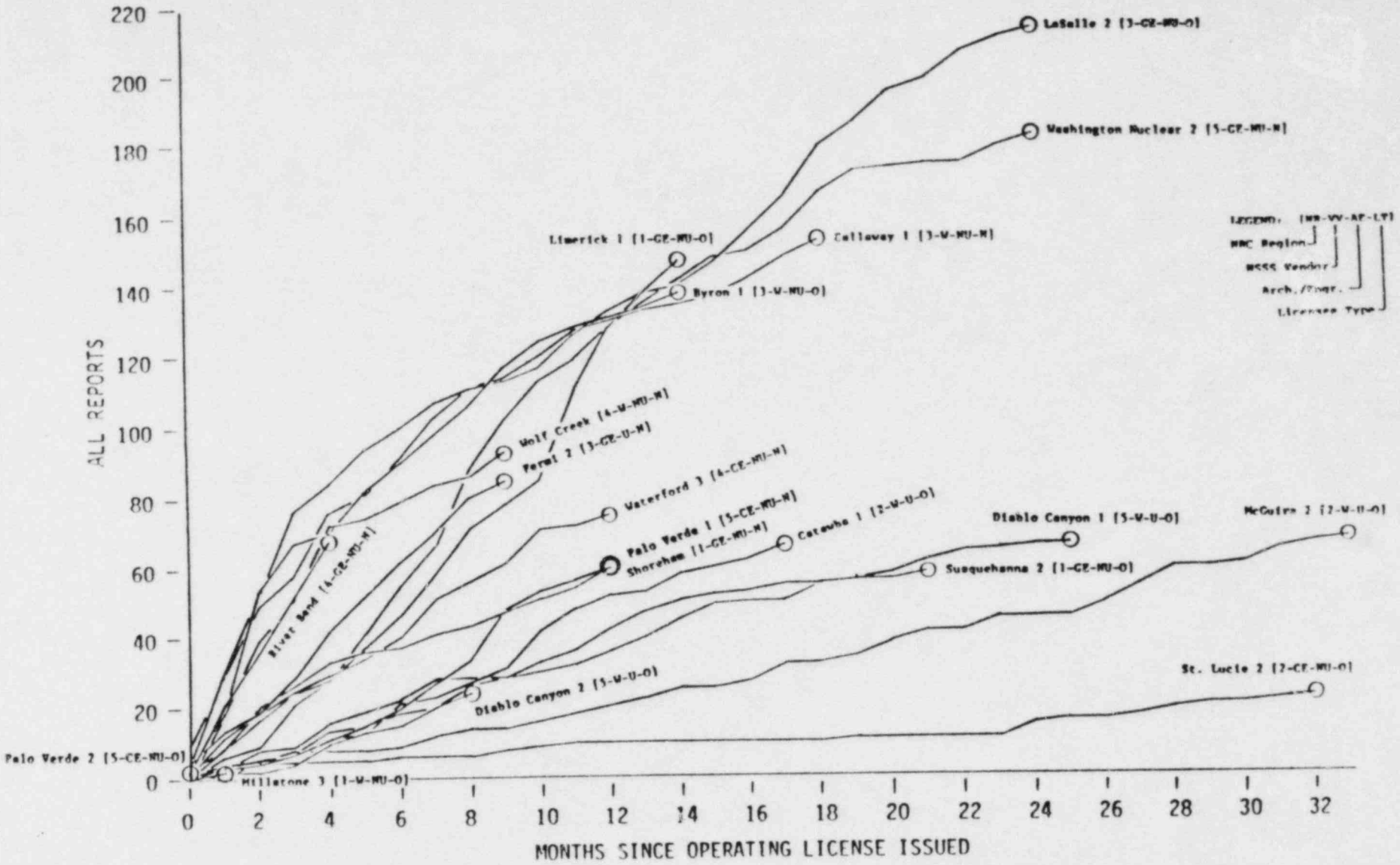


Figure 5 Cumulative Total Of All Event Reports

numbers of events, with five of eight units being within the higher grouping and the other three units just bordering on this grouping.

The lower overall reporting rate group was made up primarily of units whose nuclear steam supply system vendor was either Combustion Engineering or Westinghouse. The majority of the licensees in the lower rate group had previous nuclear experience. Units whose architect/engineer was also the licensee were predominately found (i.e., four of five) in this lower event rate group.

Conclusion Events involving the actuation of the RPS, the ESF feature systems, or a combination of both will dominate the initial year or two of operation at a newly licensed reactor. With few exceptions, a new unit will have individually unique reporting characteristics. On the whole, approximately one year of operation will be required before a decrease in overall reporting rate will be noticeable. However, for units initially experiencing higher than average RPS reporting rates, such a decrease may not be experienced. But for ESF actuations, a decrease should be expected after approximately four to eight months of operation. Overall, the units which are more likely to experience higher than average occurrence rates will (1) have had no previous nuclear reactor operating experience, or (2) have nuclear steam systems supplied by General Electric. Those units which will experience better than average occurrence rates will probably be ones whose (1) licensee had previous operating reactor experience, (2) licensee also served as the project architect/engineer, or (3) nuclear steam supply system vendor was either Westinghouse or Combustion Engineering.

2.1.3 Licensee Event Reports

While the Immediate Notification reports furnish timely information on the types of events being experienced at operating nuclear reactor units, the data provided is still preliminary. Licensee Event Reports, on the other hand, while not as timely as Immediate Notification reports, furnish in-depth information on reportable events. As a consequence, the LERs furnish many important event details and become the preferred source for event information such as causal factors.

The Office for Analysis and Evaluation of Operational Data maintains a computer-based information retrieval system for the LERs submitted after January 1981. This database is called the Sequence Coding and Search System (SCSS). The SCSS database is designed to meet two basic requirements: (1) capture all relevant technical information detailed in the LERs, and (2) provide a means such that the information is sufficiently tagged for computer retrieval. To facilitate meeting these goals, certain techniques are used to code the event information contained in each LER.

Any event reported in an LER is composed of one or more occurrences which the licensee is required by regulation to report. Each occurrence has a cause and results in some effect. Several such occurrences may be reported in a single event. These occurrences may be related to each other as a single sequence or they may be independent and reported as several different sequences. Within a sequence, an occurrence may simply be the result from some previous occurrence; however, more complex relationships are possible such as two or more

occurrences combining to initiate a single resultant occurrence, or one occurrence branching to initiate several resultant occurrences.

For the SCSS database each LER is encoded by a technical reviewer who must read and identify the individual occurrences that make up the sequences of the events being reported. This coding is so arranged that the computer can identify which occurrences are linked together and how they are linked to form a sequence. Each occurrence that is coded contains information on the cause, system and component involved, manufacturer or vendor, and failure or fault effect. Unless pertinent to the understanding of a sequence, successful occurrences are not coded, nor are corrective actions.

For this study, use of the SCSS database was limited to gathering information on the causes of the events which were occurring at the facilities under consideration. Upon examination of the LER information contained in the SCSS database for the 17 new units for which such data was available, it was found that the complex nature of the SCSS database does result in capturing, to the greatest extent possible, the individual faults and failures described in an LER. However, in attempting to identify a specific root cause which resulted in an event, e.g., a reactor scram, this complexity made such a determination very difficult, if not impossible. Such fundamental event information would have to be drawn from a careful reading and analysis of the individual LERs which were identified by SCSS as having the event characteristics under analysis. General comparative trends can be developed, though, such as the number of occurrences associated with personnel-related causes. (See Appendix B for this particular comparison.)

Other studies within AEOD are performed through the detailed reading and analysis of the events described in LERs for all of the operating U. S. power reactors, including the 19 units considered in this study. These individual AEOD studies concern RPS actuations, ESF actuations, technical specification violations, and system unavailability. A cursory review of the preliminary results of these specific studies indicates that by using aggregated SCSS data (i.e., all steps in a sequence that can be attributed to personnel or hardware problems for all units and all sequences), the split between hardware and personnel problems involved with these events is roughly in agreement with the root cause split in the detailed studies. Because of this, and since these other AEOD studies are focusing on the fundamental types of events that are being experienced at the new units (i.e., RPS actuations and ESF actuations), further analysis within the context of this new unit study was not continued.

Conclusion The complex nature of the SCSS database captures very well the detailed faults and failures described in the LERs that are being submitted by the licensees of the new units. However, this complex nature, in turn, does not lend itself to determining basic event factors such as which of the faults and failures was the root, or initiating, cause. Further detailed analysis by studying the individual LERs is necessary to determine such items. Since AEOD is presently conducting studies which specifically use this technique and address the fundamental causes of the events which are occurring at all

operating U.S. power reactors, including the new units, this will not be done in this new unit study. Instead, a follow-up report addressing only the new operating units will be produced utilizing the results of these other specific AEOD studies.

2.1.4 Monthly Operating Reports

Each month the licensees submit to the NRC reports on the operational status of each of their licensed units. The data furnished in these reports primarily summarizes factors related to unit power generation and, consequently, the data furnished by each licensee during the first months following the initial issuance of an operating license, and many months prior to declaring the unit in commercial operation, can vary widely. Even so, one of the principal factors contained in these reports is very useful and important when attempting to define comparative operational benchmarks for newly licensed reactors. This factor is the number of hours that a unit was critical (i.e., maintained a self-sustaining nuclear chain reaction) during each operational month. This information is necessary for normalizing various data items so that a more uniform unit-to-unit comparison may be performed. For this study, the pertinent critical hour data was gathered from the monthly operating reports. This data was then used in the development of some comparative benchmarks for unit operational performance. Appendix C contains a tabulation of the critical hour data used in this study.

2.2 Comparative Benchmarks

One of the goals of this study was to try and determine some useful benchmarks for comparing new unit operating experience as a function of age. To this end, the operational occurrence data previously discussed was analyzed using a simple technique known as the "5-number summary." To display the results of this analysis, the complementary display method known as the "box-and-whisker plot" was selected. A detailed explanation of these two items is given in Appendix D.

Because of the varied unit operating ages (i.e., from almost three years to just one month), it was decided to attempt to define benchmarks only for the initial year of operation. This restriction, when considered with the varied unit operating ages, meant that data covering the entire first year of operation was available for only 12 units. Since no Licensee Event Report root cause data was determined, the analysis was limited to using the Immediate Notification and monthly operating report data. Also, the time focus for the RPS actuations was shifted from the first year of operation following issuance of the initial operating license to either the first 12 months after initial criticality was achieved or, for actuations above 15 percent power, to the first 12 months after full power operation was authorized. These RPS rates were then normalized by using the unit critical hour data obtained from the monthly operating reports. The Shoreham unit was excluded from these RPS benchmark calculations since no unit critical hour data was available for it and because it had not received authorization to operate at power levels approaching 15 percent.

The results of this analysis yielded the following potential benchmark items:

1. RPS Actuation Events (Per 1000 Critical Hours) At Up To 15% Power;

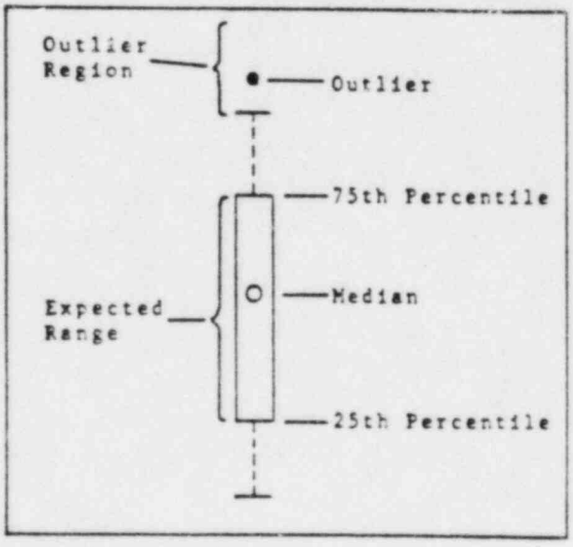
2. RPS Actuation Events (Per 1000 Critical Hours) Above 15% Power;

3. ESF Actuation (Other Than RPS) Events;

4. Security Events;

5. Miscellaneous Events;

The benchmark values for the first 12 months of operation associated with each of these items are tabulated in Appendix E. The information given in these tables is also displayed in Figures 6 and 7. These figures include the monthly median values, the normally expected range (i.e., the "box," which equates to a value falling between the twenty-fifth and seventy-fifth percentiles), the region between the expected range and the outlier region (i.e., the "whisker," which equates to a value up to 1.5 times the difference between the seventy-fifth and twenty-fifth percentile values), and the outlier region. The names of the new operating units falling into the appropriate outlier region are also given. To help interpret these figures, the following sample diagram is supplied.



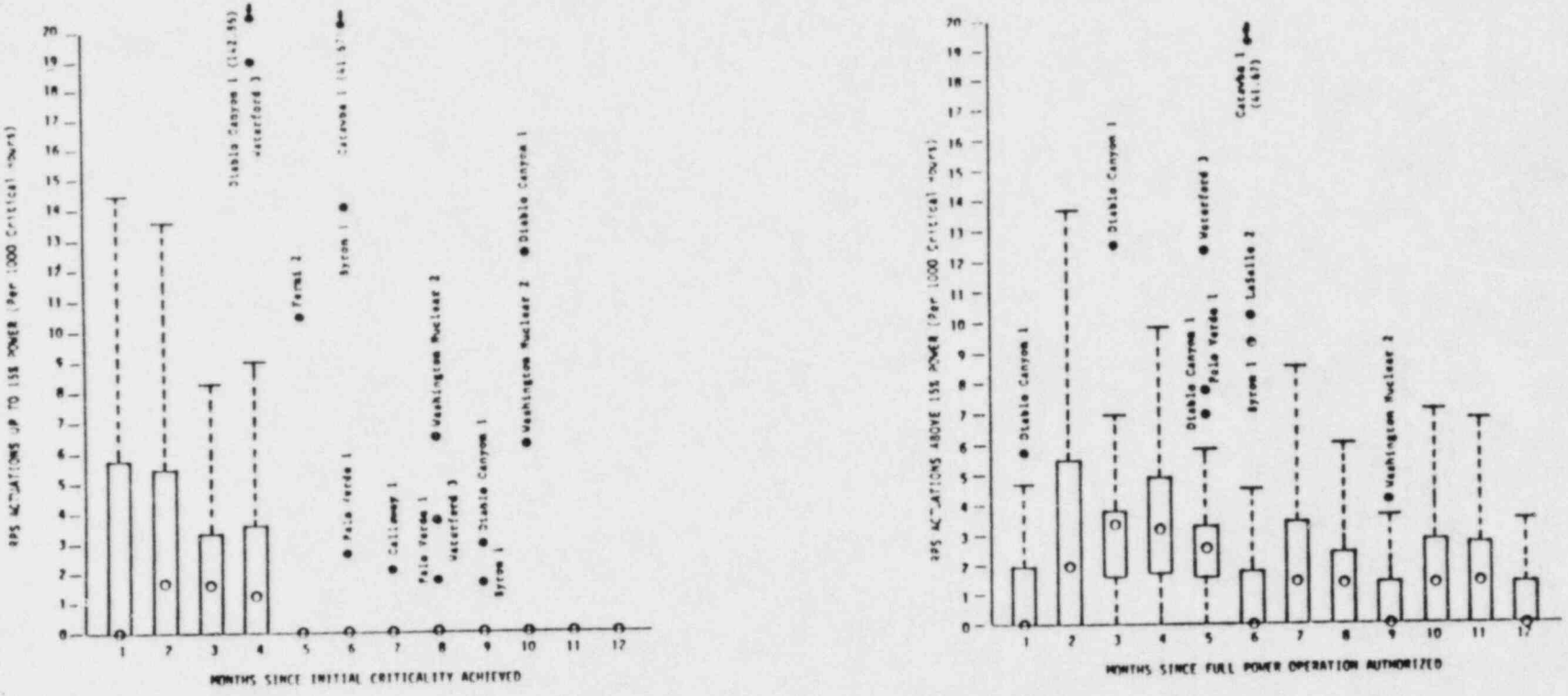


Figure 6 New Operating Units Experience Benchmarks - Reactor Protection System Actuations (Outliers Identified)

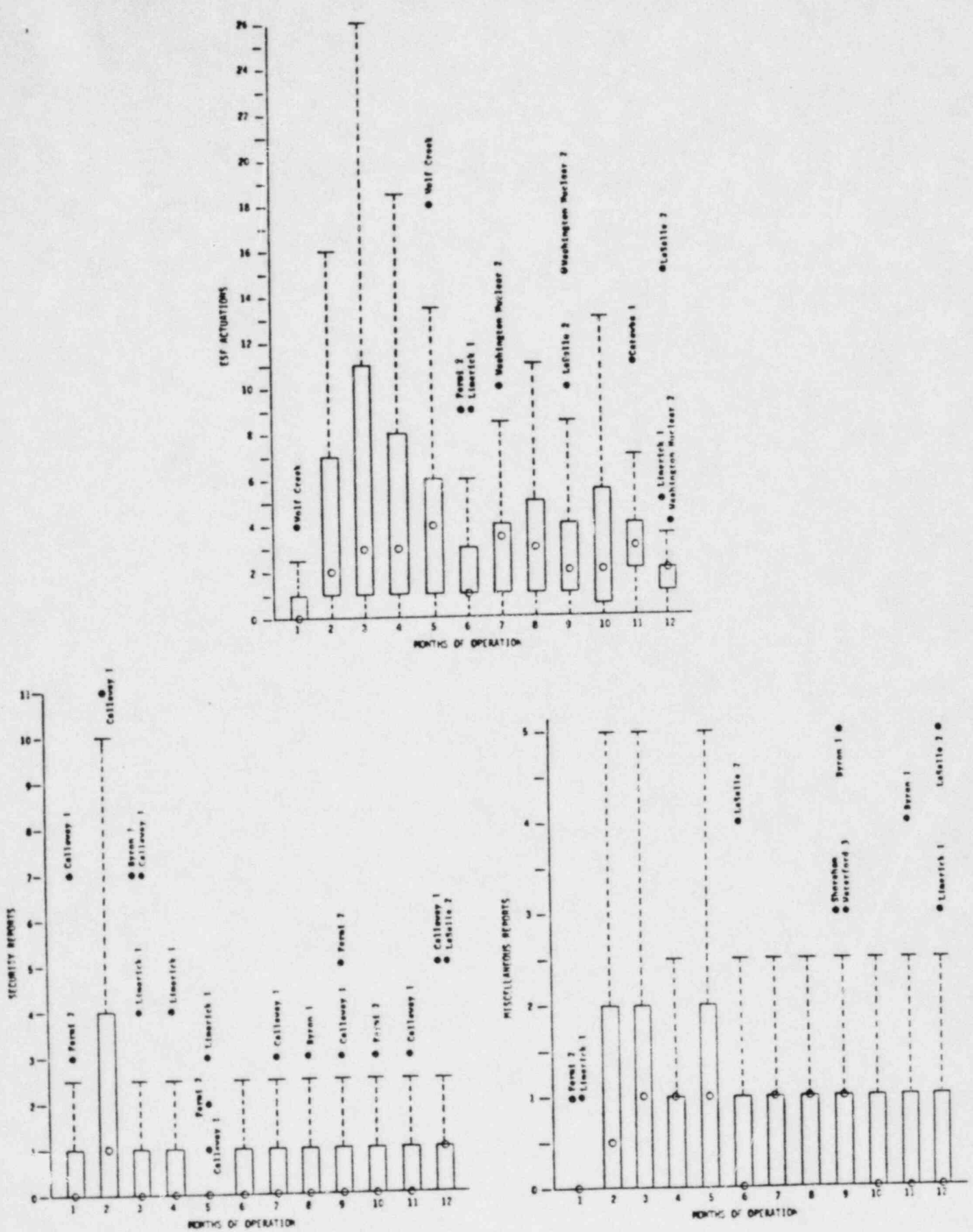


Figure 7 New Operating Units Experience Benchmarks - Event Types Other Than RPS Actuations (Outliers Identified)

As indicated by these benchmarks, the worst operating experience appeared to occur during the first four months following an operational milestone, such as achieving initial criticality. A few of the benchmarks, especially those associated with RPS actuations above 15 percent power and ESF actuations, displayed a somewhat cyclical variation with a three- to six-month period. Overall, during the first year of operation, the benchmarks showed a gradual decrease in the median occurrence values, a narrowing of the expected occurrence range, and a lowering of the outlier region threshold level.

Conclusion Based on the benchmarks developed, the basic indication is that new operating units will experience the worst occurrence rates during the first four months following the achievement of a given operational milestone such as achieving initial criticality. These rates, particularly for RPS actuations above 15 percent power and ESF actuations, will be somewhat cyclical. Overall, however, a gradual decrease in the median occurrence values, a narrowing of the expected occurrence range, and a lowering of the starting value of the outlier region will appear over the first year of operation. Thus, the overall occurrence population will tend to improve with operational experience.

2.3 Use Of Benchmarks For Unit Occurrence Experience Comparisons

The benchmarks developed in this study succinctly summarized the observed range of occurrence factors for recently licensed units during their early months of operation. While these benchmarks were simply comparative and not absolute, they still provide some reference points against which the experience of recently licensed reactors may be judged. Additionally, these benchmarks are "expected based on historical occurrence experience" and are not benchmarks of "acceptable" occurrence experience. However, by using the better units, they are examples of what occurrence experience has been achieved.

With these cautions in mind, a relative comparison and evaluation was made of the first year of operation for the new units studied. This was accomplished by first counting, on a unit basis, the number of times the monthly report rate for each benchmark factor (e.g., RPS actuations per 1000 critical hours above the 15 percent power level) fell into one of four basic categories. These categories were: (1) less than or equal to the benchmark median value; (2) exceeded the benchmark median value but remained in the expected range (i.e., remained within the twenty-fifth and seventy-fifth percentile range); (3) exceeded the benchmark expected range but was less than the outlier threshold value; and (4) fell into the benchmark outlier region. To the resulting counts, grading factors were then applied. These grading factors were: "1" for each count in the "less than or equal to the median value" category; "2" for the counts that were in the "exceeded the benchmark median value but remained in the expected range" category; "3" or counts in the category of "exceeded the expected range but was less than the outlier threshold"; and "5" for each "outlier region" category count. The sum of these four graded count categories was then computed for each unit for each of the benchmarks. For final comparative purposes, each of the resulting sums was normalized by dividing it by the appropriate total number of first year operating months for which unit data was available. Finally, comparative unit rankings were assigned for each benchmark. This was done by assigning a rank of "1" to the unit having the lowest normalized grade in a given benchmark. Appendix F contains a tabulation of the net benchmark count data.

The results of the normalized graded count category calculations are summarized in Table 2. The associated comparative unit rankings for each benchmark item are summarized in Table 3. Note that in Table 2, a value of 1.00 is the lowest possible value and indicates the unit having the best "expected based on occurrence experience" value for the particular benchmark being considered. Similarly, a value of 1 in Table 3 indicates the unit displaying the best ranking and, thus, should be considered to be the best example of what level of occurrence experience was achieved for that particular benchmark. Discussions of the relative performance of each new unit studied based on these benchmark findings follow.

Byron 1 For the 14 months since an operating license was issued to Byron 1, this unit has experienced one of the highest continuing occurrence rates of any of the 19 new units studied. Based on the occurrence experience benchmarks, over 50 percent of the event type benchmarks exceeded the median values, with over 30 percent being outside the expected range and some 10 percent being classified as outliers. In terms of occurrence experience rankings, the best ranking achieved by Byron 1 in any individual area was an 8 in the category of RPS actuations above 15 percent power, with most at 10 or below. Thus, Byron 1 possesses next to the worst record of the 19 units considered with regard to the new unit occurrence experience factors studied for the initial year of operation.

Callaway 1 Callaway 1 has been displaying some of the highest occurrence rates of the 19 units studied during its first 18 months of operation. Fifty-five percent of the event benchmarks exceeded the median value, with 15 percent between the expected range and the outlier threshold and 15 percent classified as outliers. Its best ranking in a major event category was a 9 in RPS actuations up to 15 percent power. Based only on these factors for the benchmarks considered, Callaway 1 would rank as the worst of the 19 units for operational experience during its first year of operation.

Catawba 1 Based strictly on the number of reports generated, the indications were that Catawba 1 has had much better occurrence experience than many of the other reactors studied. However, when the number and types of occurrences given in these reports were compared, some of this apparent advantage disappeared. In fact, the best occurrence experience benchmark ranking for Catawba 1 was a value of 5 in security events and the poorest ranking was a 12 in RPS actuations above 15 percent power. Six percent of its event benchmarks were in the outlier category. This is about the average value for the 19 units considered. These factors, when considering only the graded benchmarks, indicate that the Catawba 1 initial operational year occurrence experience was just average.

Diablo Canyon 1 After a long period after completion before finally achieving an operating license, Diablo Canyon 1 has shown one of the smoothest periods of initial operation of the units studied. This smoothness, however, does not necessarily translate into a good occurrence experience rating during the initial start-up year. One area of trouble appeared in its history of RPS actuations, where Diablo Canyon 1 ranked 14th and 8th, respectively, for actuations up to 15 percent power and for actuations above 15 percent power. Similar rankings were found in the other event-related benchmarks. On a percentage basis, slightly more than 70 percent of the event benchmark values

Table 2 Unit Normalized Individual Performance Benchmark Values

UNIT	RPS ACTUATIONS (Per 1000 Critical Hrs)		EVENT TYPES OTHER THAN RPS ACTUATIONS		
	Up To 15% Power	Above 15% Power	ESF Actuations	Security	Misc.
BYRON 1	1.91	2.00	1.92	2.25	2.25
CALLAWAY 1	1.67	2.17	2.00	4.00	1.25
CATAWBA 1	1.57	2.14	1.58	1.08	1.42
DIABLO CANYON 1	2.20	2.00	1.67	1.25	1.50
DIABLO CANYON 2	1.60	2.40	1.00	1.22	1.33
FERMI 2	2.29	1.00	2.10	2.90	1.70
LaSALLE 2	1.08	1.50	2.25	1.92	2.50
LIMERICK 2	1.00	1.00	2.58	2.33	1.83
McGUIRE 2	1.00	2.00	1.08	1.00	1.08
MILLSTONE 3	---	---	1.00	1.00	1.00
PALO VERDE 1	2.00	2.00	1.25	1.33	1.42
PALO VERDE 2	---	---	3.00	1.00	1.00
RIVER BEND	2.00	1.00	2.00	2.20	1.60
SHOREHAM	---	---	1.25	1.42	1.83
St. LUCIE 2	1.00	1.60	1.00	1.17	1.00
SUSQUEHANNA 2	1.00	1.36	1.17	1.00	1.33
WASHINGTON NUCLEAR 2	2.10	2.25	2.92	1.42	1.33
WATERFORD 3	2.50	2.60	1.75	1.08	1.83
WOLF CREEK	1.63	1.57	2.60	1.50	1.20

(NOTE: A Value of 1.00 Is Equivalent to the BEST Performance.)

Table 3 Unit Individual Experience Benchmark Rankings

UNIT	RPS ACTUATIONS (Per 1000 Crit Hrs)		EVENT TYPES OTHER THAN RPS ACTUATIONS		
	Up To 15% Power	Above 15% Power	ESF Actuations	Security	Misc.
Byron 1	10	8	11	16	18
Callaway 1	9	13	12	19	6
Catawba 1	6	12	8	5	10
Diablo Canyon 1	14	8	9	9	12
Diablo Canyon 2	7	15	1	8	7
Fermi 2	15	1	14	18	14
LaSalle 2	5	5	15	14	19
Limerick 1	1	1	16	17	15
McGuire 2	1	8	4	1	4
Millstone 3	---	---	1	1	1
Palo Verde 1	11	8	6	10	10
Palo Verde 2	---	---	19	1	1
River Bend	11	1	12	15	13
Shoreham	---	---	6	11	15
St. Lucie 2	1	7	1	7	1
Susquehanna 2	1	4	5	1	7
Washington Nuclear 2	13	14	18	11	7
Waterford 3	16	16	10	5	15
Wolf Creek	8	6	17	13	5

(NOTE: A Value of "1" Is Equivalent to the BEST Performance.)

were at or below the median, but over 10 percent were classified as outliers. Based on just the factors analyzed, these somewhat conflicting indications result in ranking the occurrence experience of Diablo Canyon 1 during its initial year of operation as poorer than average.

Diablo Canyon 2 Diablo Canyon 2 appeared to have profited from the start-up occurrence experience of its older twin, Diablo Canyon 1. The one detractor from this improvement, though, was poor experience with respect to RPS actuations above 15 percent power, which at a ranking of 15 was second to the worst ranking in this category. The overall event benchmark occurrence rate percentages have improved, however, with over 75 percent being at or below the median value and less than 3 percent in the outlier region. The net result of this occurrence experience during the initial year of operation is that Diablo Canyon 2 was one of the best of all the units ranked based on the factors studied.

Fermi 2 Of the 19 units studied, Fermi 2 has had one of the higher occurrence rates. When these occurrences were compared to the benchmarks, Fermi 2 showed one of the poorest records. Four of the five event benchmark rankings were at or below 14. Over 16 percent of the occurrences were categorized as outliers. Only 55 percent were at or below the median value. These factors indicate that the initial operational occurrence experience of Fermi 2 for the factors analyzed was one of the poorest of the units studied.

LaSalle 2 One of the oldest units studied, LaSalle 2 has had a varied initial operating history. It has one of the poorest report records, except for RPS actuations where it ranked fifth in both actuations up to and over 15 percent power. When all occurrences are considered, less than 57 percent of the occurrences were at or below the median; however, almost 80 percent of the occurrences were within the event benchmark expected range. On the other hand, the event outlier occurrence rate of 10 percent was one of the higher values. The result of these somewhat conflicting items for the factors studied yields an overall occurrence experience indication for LaSalle 2 of poorer than average and bordering on being one of the poorest of the 19 units considered for the initial year of operation.

Limerick 1 Having had the best overall RPS actuation ranking, Limerick 1 still has had a rather poor initial history of operation when other items, such as a ranking of 16 for ESF actuations, were considered. Overall, these variations indicate that occurrence experience of Limerick 1 during the first year of operation was below average when compared with all of the other units studied.

McGuire 2 McGuire 2 was the oldest unit studied. It ranked best in number of RPS actuations up to 15 percent power and security reports but eighth in RPS actuations above 15 percent power. Over 92 percent of all the event benchmark factors were at or below the median value with no outliers. Overall, this equates to McGuire 2 being above average and one of the better units for the factors considered during the first year of unit operation.

Millstone 3 With just a little over one month of operational data, little could be determined about the future occurrence experience at Millstone 3. From the few indications available from the benchmarks, however, this initial period may be fairly good since its occurrence experience ranking for the

applicable benchmarks was the best possible. Until a few more months of operational data is available, however, no meaningful overall initial ranking in relationship to the other units and factors studied can be made.

Palo Verde 1 Palo Verde 1 has had a rather mediocre initial year of operation, with the highest benchmark ranking being a 6 and the lowest an 11. The one outstanding item was that less than 4 percent of the occurrence counts fell into the outlier category. The net result is that the initial operational occurrence experience at Palo Verde 1 would rank it as the average unit out of the 19 units studied for the factors analyzed over the first year of operation.

Palo Verde 2 The younger of the two operating Palo Verde units studied, the very brief history of Palo Verde 2 is very confusing. With less than one month of operational experience, Palo Verde 2 led all units in the occurrence rate for ESF events. This unfortunate rate, if continued, may result in an overall poor occurrence experience. However, it was equal to the best units in the other categories for which benchmark data was available. These confusing indications, like Millstone 3, indicate that additional data is needed before a meaningful unit initial year of operational occurrence experience comparison can be made.

River Bend Like Millstone 3 and Palo Verde 2, little operational history is available for River Bend. But from the data that is available, when compared to like factors of the other 19 new operating units, the initial operational experience is one of the poorest. The only bright spot was that it was one of the best units insofar as RPS actuations above 15 percent power were concerned.

Shoreham For the benchmarks which were applicable to Shoreham, less than 12 percent of the event values exceeded the expected range and over 66 percent were at or below the median values. As such, the indications are that Shoreham has had a better than average initial start up. One area which could modify this assessment, however, is its RPS actuation rates, once operational data is available for this item.

St. Lucie 2 Second in operating age only to McGuire 2, St. Lucie 2 had an exemplary initial period of operation. A potentially significant jump in occurrences was noticeable, however, over the last eight months, some two years into operation. But based on the first 12 months of operation, the initial operating occurrence experience for the factors studied ranked St. Lucie 2 as next to the best unit studied.

Susquehanna 2 Of the units which had more than one year of experience, Susquehanna 2 demonstrated the best performance for the initial year of operation. Over 98 percent of its benchmark event values during the initial year of operation fell within the expected range, with over 84 percent at or below the median value and no outliers. This outstanding occurrence experience for the factors considered indicates that Susquehanna 2 ranked best of all the 19 units studied as rated on the benchmarks considered for the initial year of operation.

Washington Nuclear 2 The initial and continuing occurrence experience history of Washington Nuclear 2 has been one of the worst of all the units investigated. Almost 50 percent of the occurrences experienced during the

first year of operation exceeded the median experience benchmark values, with 10 percent in the outlier range. The net result of this occurrence experience is an overall initial year of operation ranking for Washington Nuclear 2 of being one of the poorest of the new units for the items studied.

Waterford 3 The initial performance of Waterford 3 has shown a varied history. Waterford 3 has had one of the poorest records of all units for RPS actuations, with rankings of 16 for actuations both up to and above 15 percent power. Its record as based on events other than RPS actuations is mediocre, with one ranking above the median and two below. More than 7 percent of the benchmark values were in the outlier range, but more than 55 percent were at or below the median value. When these items are considered, the occurrence experience record of Waterford 3 during its initial year of operation is considered to be below the average of the 19 units studied.

Wolf Creek The early operational occurrence experience history of Wolf Creek has varied. However, the overall record would indicate a below average start-up period. Thus, Wolf Creek, based on the occurrence benchmarks studied for its initial period of operation, is ranked as being below average.

Conclusion Using benchmarks developed from information contained in databases associated with the Immediate Notification and monthly operating reports, comparative unit occurrence experience of the 19 units studied could be analyzed. Over the first year of operation and based solely on the indications given by the event benchmarks, the best records were demonstrated by Susquehanna 2 and St. Lucie 2. Again, based on the event benchmarks studied, the units found to have the worst experience record during their first year of operation were Callaway 1 and Byron 1. Likewise, for the event benchmarks studied, Palo Verde 1 demonstrated what would be considered to be an average occurrence experience during the initial year of operation. While these findings for the 19 units studied are only comparative and are not absolute, they do give indications and examples of what type of initial operational experience has been achieved for the benchmarks considered. Thus, the performance illustrated by the Susquehanna 2 and St. Lucie 2 units should be used as examples of what type of initial operational occurrence experience has been achieved.

3.0 SUMMARY

It is generally acknowledged that newly licensed reactors experience a comparatively higher frequency of reportable events during their first two years of operation than in their later years of operation. Many of these events result in challenges to safety systems or a reduction of the operating margin of the facility, e.g., violations of technical specifications. This leads to a heightened safety concern during this initial operational period. Such concern was highlighted in the 1985 Policy and Planning Guidance for the NRC as a commitment to "... continue to closely monitor the first two years of operation of new plants coming on line, particularly those of licensees who have no prior experience with nuclear plants." Since NRC program resource limitations do not allow increased coverage in all operating areas for all new plants, the Office for Analysis and Evaluation of Operational Data undertook a study of the initial operational experience characteristics of 19 U. S. nuclear power reactors that received operating licenses between 1983 and 1985. These

units were: Byron 1, Callaway 1, Catawba 1, Diablo Canyon 1 and 2, Fermi 2, LaSalle 2, Limerick 1, McGuire 2, Millstone 3, Palo Verde 1 and 2, River Bend, Shoreham, St. Lucie 2, Susquehanna 2, Washington Nuclear 2, Waterford 3, and Wolf Creek.

The prime intent of this AEOD study was to try to characterize the event trends and patterns being experienced by this group of newly licensed units. From these trends and patterns, it was hoped that common characteristics would be identified which could then be used to help focus the available resources on those areas which have the largest safety significance for new units. To this end, computerized event data was analyzed. The items studied included: (1) RPS actuations; (2) events other than RPS actuations, such as ESF actuations; and (3) principal features, such as causes, associated with the events that were occurring.

It was found that while each unit displayed distinct and unique initial operation characteristics, event information being received by the NRC is sufficient to indicate preliminary occurrence experience trends approximately two months after license issuance. This could allow resources to be focused fairly early in unit life on those units which are exhibiting poor occurrence experience.

Based on the analyzed data, the indications are that of the major types of events which will occur during the initial period of operation of a newly licensed unit, RPS and ESF actuations dominate. The RPS actuation rates at individual units should remain fairly constant during the initial operating history. If this is a high rate to begin with, it will tend to stay high; if low, it will tend to stay low. Thus, a unit occurrence experience improvement for RPS actuations may not be readily distinguishable over the first year or two of operation. In contrast to this, after approximately four to eight months after initial license issuance, a unit occurrence experience improvement should appear for ESF actuations other than RPS actuations. These trends, when combined with the minor trend contributions associated with report types other than RPS and ESF actuations, indicate that approximately one year of licensed operation will be required before a net decrease in the individual overall event reporting rate is realized.

Further analysis revealed that the 19 units clustered into two fairly equally divided groups. Five out of the seven units whose nuclear steam supply systems were manufactured by General Electric were experiencing the high occurrence rates. Also, the units of new licensees were found to be experiencing high numbers of events, with five of eight units being within the higher grouping and the other three units just bordering on this grouping. The lower overall reporting rate group was made up primarily of units whose nuclear steam supply system vendor was either Combustion Engineering or Westinghouse. The majority of the licensees in the lower rate group had previous nuclear experience. Units whose architect/engineer was also the licensee were predominately found (i.e., four of five) in this lower event rate group.

From the study of the SCSS database, it was determined that while comparative trends on event features could be obtained, fundamental event information, such as root causes, would have to be drawn from detailed reading and analysis of

the individual LERs. Since other AEOD studies are presently undertaking such a task and include new operating units, further analysis within this new unit study was deferred. As soon as the results of these other AEOD studies are finalized, a follow-up study using these results will be conducted which addresses specifically only new operating units.

By applying simple mathematical techniques to the data, it was possible to develop several benchmarks which may be used in analyzing and comparing new unit operational occurrence experience. These benchmarks are applicable to the first year of operation following an appropriate licensing milestone, such as achieving initial criticality. The basic indication given by these benchmarks is that new operating units will experience the worst occurrence rates during the first four months following the achievement of a given operational milestone, such as achieving initial criticality. These rates, particularly for RPS actuations above 15 percent power and ESF actuations, will be somewhat cyclical. Overall, however, these rates do show a gradual decrease in the median occurrence values, a narrowing of the expected occurrence range, and a lowering of the starting value of the outlier region. Thus, the overall number of occurrences tends to improve with operational experience.

Finally, using the performance benchmarks developed, a comparative occurrence experience analysis was conducted of the 19 units investigated in this study. The indications which resulted from this endeavor were that the best comparative initial operation was experienced by Susquehanna 2 and St. Lucie 2. The units found to have experienced the worst initial period of operation were Callaway 1 and Byron 1. While only comparative, these findings do give indications and examples of what type of initial operational performance has been achieved for the benchmarks considered. Such indicators should assist both regulators and licensees in analyzing the performance of newly licensed units and to help point out areas of strengths and weaknesses at each new reactor.

Appendices

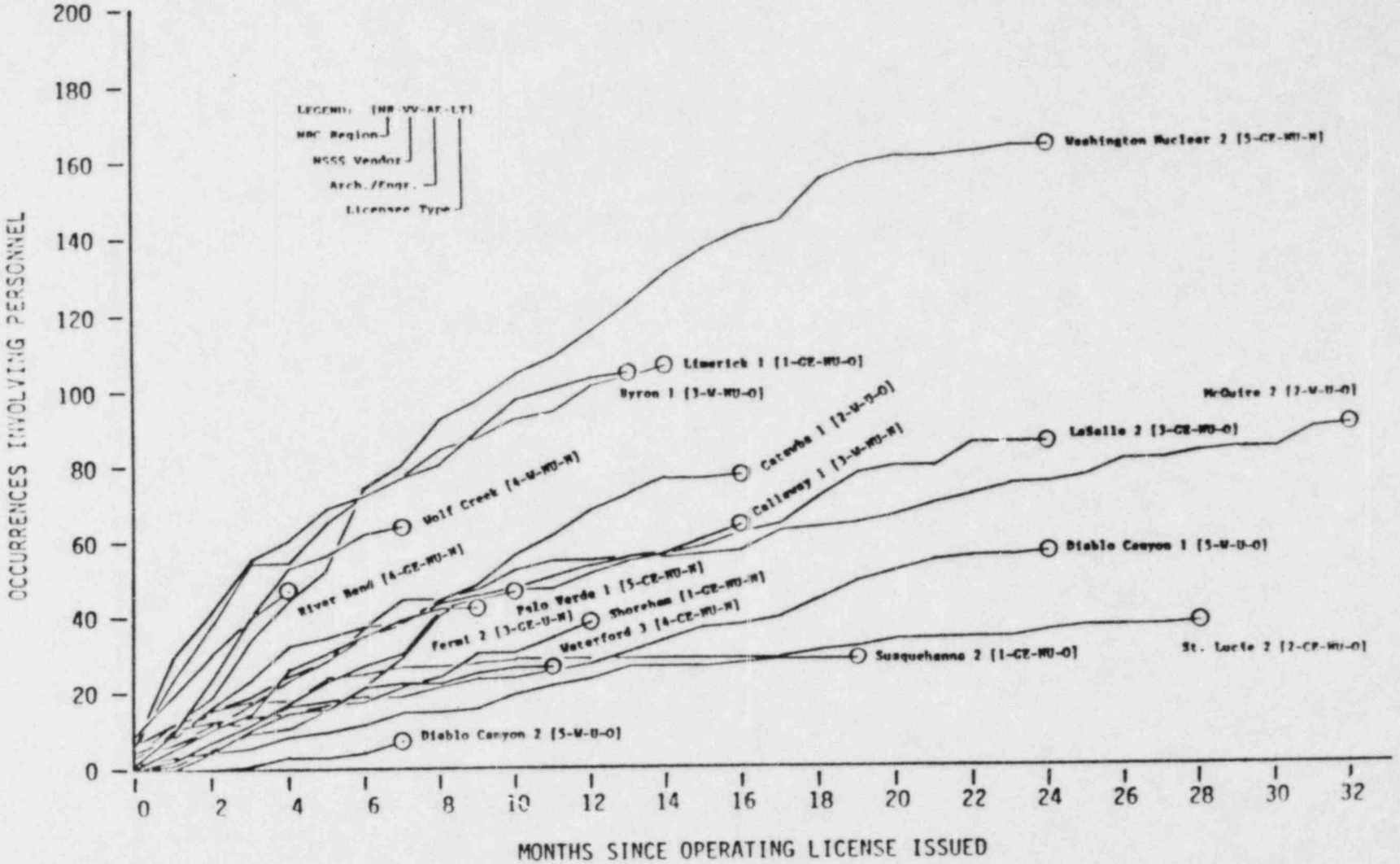
Appendix A

Unit Operational Milestone Data

UNIT	Initial Operation License Date	Initial Critical Date	Full Power License Date
Byron 1	31-Oct-84	02-Feb-85	19-Feb-85
Callaway 1	11-Jun-84	02-Oct-84	18-Oct-84
Catawba 1	18-Jul-84	07-Jan-85	17-Jan-85
Diablo Canyon 1	08-Nov-83	29-Apr-84	02-Nov-84
Diablo Canyon 2	26-Apr-85	19-Aug-85	26-Aug-85
Fermi 2	20-Mar-85	21-Jun-85	16-Jul-85
LaSalle 2	16-Dec-83	10-Mar-84	23-Mar-84
Limerick 1	26-Oct-84	22-Dec-84	08-Aug-85
McGuire 2	03-Mar-83	08-May-83	27-May-83
Millstone 3	25-Nov-85	23-Jan-86	25-Nov-85
Palo Verde 1	31-Dec-84	25-May-85	01-Jun-85
Palo Verde 2	09-Dec-85	18-Apr-86	NA
River Bend	29-Aug-85	31-Oct-85	20-Nov-85
Shoreham	07-Dec-84	15-Feb-85	NA
St Lucie 2	06-Apr-83	02-Jun-83	10-Jun-83
Susquehanna 2	23-Mar-84	08-May-84	27-Jun-84
Washington Nuclear 2	20-Dec-83	19-Jan-84	13-Apr-84
Waterford 3	18-Dec-84	04-Mar-85	16-Mar-85
Wolf Creek	11-Mar-85	22-May-85	04-Jun-85

Appendix B

Sample Unit Comparative Trend Based On SCSS Data



Appendix C

Unit Operation Critical Hours Data

UNIT	1983 Jan-Dec	1983 Jan	1983 Feb	1983 Mar	1983 Apr	1983 May	1983 Jun	1983 Jul	1983 Aug	1983 Sep	1983 Oct	1983 Nov	1983 Dec	1984 Jan	1984 Feb	1984 Mar	1984 Apr	1984 May	1984 Jun	1984 Jul	1984 Aug	1984 Sep	1984 Oct	1984 Nov	1984 Dec
Byron 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	393.4	258.0	621.9	608.6	619.4	243.5	660.6	704.0	593.5	0.0	327.5
Callaway 1	—	—	—	—	—	—	—	—	—	—	532.0	670.0	302.5	724.3	649.9	658.2	479.7	720.8	639.9	699.5	731.5	720.0	716.8	695.0	697.2
Calvert 1	—	—	—	—	—	—	—	—	—	—	—	—	—	DNA	DNA	DNA	DNA	DNA	48.0	708.2	744.0	720.0	390.9	305.0	696.3
Diablo Canyon 1	—	—	—	—	DNA	DNA	0.0	7.0	18.0	0.0	0.0	347.0	713.0	79.8	401.8	650.8	0.0	649.3	720.0	744.0	725.9	720.0	703.5	696.3	639.5
Diablo Canyon 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	206.3	0.0	536.3	550.8	572.0
Farat 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	213.9	537.4	517.0	445.0	192.0	0.0	0.0
LaSalle 2	—	—	—	—	124.5	583.6	588.7	613.7	608.0	292.6	619.6	705.1	720.0	618.8	744.0	655.8	0.0	0.0	0.0	0.0	266.6	679.9	720.0	492.5	0.0	218.8
Limerick 1	—	—	—	—	—	—	—	—	—	—	—	—	37.7	740.1	202.3	19.7	371.7	0.0	0.0	0.0	557.7	654.9	603.6	553.4	670.8
McGuire 2	DNA	DNA	DNA	707.0	694.5	641.9	713.5	499.4	199.0	695.0	687.8	629.6	670.6	595.0	0.0	0.0	0.0	603.4	636.2	330.3	744.0	720.0	714.0	703.6	424.8
Millstone 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Palo Verde 1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	166.0	695.0	397.0	122.0	533.5	386.3	3.5	583.8
Palo Verde 2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
River Bend	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20.6	568.8	487.7
Shoreham	—	—	—	—	—	—	—	—	—	—	—	—	—	—	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA	DNA
St Lucie 2	DNA	DNA	733.9	687.5	744.0	719.0	744.0	720.0	744.0	710.6	577.9	287.2	192.6	518.5	744.0	672.0	670.5	539.1	744.0	720.0	737.9	172.4	306.7	745.0	720.0	671.1
Susquehanna 2	—	—	—	—	—	—	DNA	DNA	458.7	581.9	612.8	492.5	0.0	0.0	554.5	408.0	661.9	619.0	688.0	664.7	610.7	691.5	720.0	719.6	720.0	617.8
Washington Nuclear 2	—	—	13.9	0.0	0.0	414.3	729.2	324.8	243.9	465.7	552.5	480.6	415.6	725.1	636.2	501.6	658.4	691.7	74.1	81.3	692.5	735.3	720.0	745.0	619.6	744.0
Waterford 3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	290.5	512.2	440.4	105.4	323.1	0.0	177.8	537.3	720.0	462.1
Wolf Creek	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	159.1	349.1	545.0	628.2	651.0	675.3	720.0	744.0

Appendix D

5-Number Summary & Box-and-Whisker Diagram

In attempting to develop simple benchmark values which could be used to describe typical characteristics of new unit operational performance, it was decided to use a simple exploratory data analysis method known as the "5-number summary." "Box-and-Whisker" diagrams were selected to display the results.

A "5-number summary" is a simple method of describing the basic character of a group of values, such as the number of ESF actuations experienced by all units during a given month of operation. As implied in the name, a 5-number summary defines the group character by five unique points. These are:

- The "extreme" --- the highest and lowest values found in a group
- The "median" --- the single middle value or mean of the two middle values between the extremes of a group
- The "hinges" --- the middle value or mean of the two middle values between each extreme and the median.

Thus, 50 percent of all observations in a group will lie between the hinge values, with 25 percent below the lower hinge and 25 percent above the upper hinge.

While the 5-number summary defines the basic character of a group of values, it does not indicate whether certain values are apparently far beyond the others, i.e., they are outliers. To compensate for this, a simple extension to the 5-number summary is made. This extension defines an outlier as any value that lies at least one "step" beyond a hinge value; with a step equal to 1.5 times the difference between the hinge values. Thus, for a group of observations, an observation shall be considered to be an outlier if its value is 1.5 times the difference between the upper and lower hinge values.

To visually display the results of a 5-number summary analysis with outliers, a simple diagram known as a "box-and-whisker" is used. Such a display is made up of several basic components; these are:

- The "box" --- a thin rectangle, usually vertical, stretching from hinge to hinge
- The "whiskers" --- dashed lines, ending in cross bars, stretching between the box hinge values and the "fence" values
- The "fence" --- 1 step outside the hinge values
- The "median" --- a bar or similar indicator within the "box" indicating the median value

- o The "outliers" --- a dot or similar indicator for observations falling outside the "fence" values

An example 5-number summary and box-and-whisker display follows.

Observation values: 2, 4, 6, 8, 10, 13, 14, 29, 30

Number of observations: 9

Extremes: 2 and 30

Median: 10

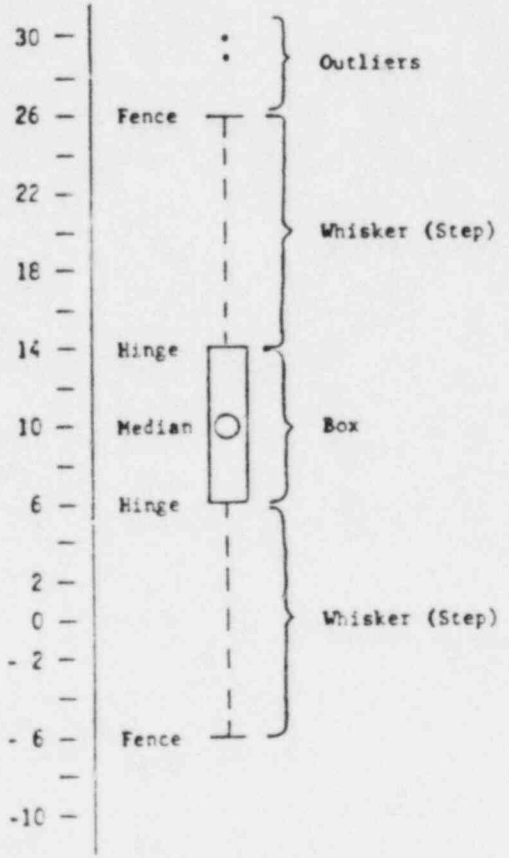
Hinges: 6 and 14

Step: 1.5 x (14-6) = 12

Fences: 6 - 12 = -6 and 14 + 12 = 26

Outliers: 29 and 30

"Box-and-Whisker Diagram"



Appendix E

Monthly Occurrence Benchmark Values

The benchmark values associated with each of these items for each of the first 12 months of operation are given in Tables E.1 and E.2. Included in each table are the calculated monthly values for the median, the normally expected range (i.e., falling between the twenty-fifth and seventy-fifth percentiles), and the starting point for the upper outlier region (i.e., greater than 1.5 times the difference between the seventy-fifth and twenty-fifth percentile values).

Table E.1 Benchmark Values - Reactor Protection System Actuations

MONTH OF OPERATION	RPS ACTUATIONS UP TO 15% POWER (Per 1000 Critical Hours) [Since Initial Criticality]			RPS ACTUATIONS ABOVE 15% POWER (Per 1000 Critical Hours) [Since Full Power Authorized]		
	Median Value	Expected Range	Outlier Region	Median Value	Expected Range	Outlier Region
1	0.00	0.00-5.78	14.45	0.00	0.00-1.88	4.70
2	1.71	0.00-5.43	13.58	1.95	0.00-5.50	13.75
3	1.61	0.00-3.31	8.28	3.27	1.59-3.73	6.94
4	1.21	0.00-3.58	8.95	3.18	1.63-4.90	9.81
5	0.00	0.00-0.00	0.00	2.56	1.54-3.29	5.92
6	0.00	0.00-0.00	0.00	0.00	0.00-1.81	4.53
7	0.00	0.00-0.00	0.00	1.46	0.00-3.43	8.58
8	0.00	0.00-0.00	0.00	1.42	0.00-2.41	6.03
9	0.00	0.00-0.00	0.00	0.00	0.00-1.45	3.63
10	0.00	0.00-0.00	0.00	1.38	0.00-2.86	7.15
11	0.00	0.00-0.00	0.00	1.41	0.00-2.73	6.83
12	0.00	0.00-0.00	0.00	0.00	0.00-1.42	3.55

Table E.2 Benchmark Values - Event Types Other Than RPS Actuations

MONTH OF OPERATION (Since operating license issued)	ESF ACTUATIONS			SECURITY			MISCELLANEOUS EVENTS		
	Median Value	Expected Range	Outlier Region	Median Value	Expected Range	Outlier Region	Median Value	Expected Range	Outlier Region
1	0	0-1	2h	0	0-1	2h	0	0-0	0
2	2	1-7	16	1	0-4	10	1	0-2	5
3	3	1-11	26	0	0-1	2h	1	0-2	5
4	3	1-8	18	0	0-1	2h	1	0-1	2h
5	4	1-6	13h	0	0-0	0	1	0-2	5
6	1	1-3	6	0	0-1	2h	0	0-1	2h
7	3h	1-4	8h	0	0-1	2h	1	0-1	2h
8	3	1-5	11	0	0-1	2h	1	0-1	2h
9	2	1-4	8h	0	0-1	2h	1	0-1	2h
10	2	h-5h	13	0	0-1	2h	1	0-1	2h
11	3	2-4	7	0	0-1	2h	0	0-1	2h
12	2	1-2	3h	h	0-1	2h	0	0-1	2h

(Note: A value with an "h" in it is a "half-value," e.g., 9h = 9.5)

Appendix F

5-Number Summary Benchmark Items Count Data

Listed in Table F.1 are counts of the number of times that the monthly report rate at each unit for each benchmark item met one of the following criteria:

- Rate was less than or equal to the median value (Denoted as "<Median")
- Rate was greater than the median value but less than or equal to the upper hinge (i.e., seventy-fifth percentile) value and, thus, was within the normally expected range (Denoted as ">Median")
- Rate was in the upper fence range, i.e., greater than the upper hinge value but lower than the outlier threshold value (Denoted as "Fence")
- Rate was in the upper outlier region (Denoted as "Outlier")

A summary of the total number of counts in each criteria category is also included, along with an associated listing of the percentages which these individual totals represent of the total number of unit counts.

Table F.1 Unit Performance Benchmark 5-Number Summary Count Data

UNIT NAME	RPS - UP TO 15% POWER					RPS - >15% POWER				
	Months	<Median	>Median	Fence	Outlier	Months	<Median	>Median	Fence	Outlier
Byron 1	11	6	2	2	1	11	5	3	2	1
Callaway 1	12	8	2	1	1	12	4	6	2	0
Catawba 1	7	6	0	0	1	7	4	0	2	1
Diablo Canyon 1	10	7	0	0	3	12	7	2	1	2
Diablo Canyon 2	5	3	1	1	0	5	2	1	1	1
Fermi 2	7	3	1	2	1	6	6	0	0	0
LaSalle 2	12	11	1	0	0	12	9	2	0	1
Limerick 1	12	12	0	0	0	5	5	0	0	0
McGuire 2	2	2	0	0	0	2	1	0	1	0
Millstone 3										
Palo Verde 1	8	6	0	0	2	7	3	3	0	0
Palo Verde 2										
River Bend	3	1	1	1	0	2	2	0	0	1
Shoreham										
St. Lucie 2	5	5	0	0	0	5	3	1	1	0
Susquehanna 2	10	10	0	0	0	11	7	4	0	0
Washington Nuclear 2	12	9	1	0	2	12	4	3	4	1
Waterford 3	10	4	1	3	2	10	3	0	6	1
Wolf Creek	8	5	1	2	0	7	4	2	1	0

Table F.1 (Continued) Unit Performance Benchmark 5-Number Summary Count Data

UNIT NAME	ESF REPORTS					SECURITY REPORTS				
	Months	<Median	>Median	Fence	Outlier	Months	<Median	>Median	Fence	Outlier
Byron 1	12	6	1	5	0	12	5	3	2	2
Callaway 1	12	4	4	4	0	12	1	2	1	8
Catawba 1	12	8	3	0	1	12	11	1	0	0
Diablo Canyon 1	12	11	0	1	0	12	9	3	0	1
Diablo Canyon 2	9	9	0	0	0	9	7	2	0	0
Fermi 2	10	4	3	2	1	10	4	1	1	4
LaSalle 2	12	4	5	1	2	12	6	3	2	1
Limerick 1	12	2	5	3	2	12	5	1	3	3
McGuire 2	12	11	1	0	0	12	12	0	0	0
Millstone 3	2	2	0	0	0	2	2	0	0	0
Palo Verde 1	12	9	3	0	0	12	9	2	1	0
Palo Verde 2	1	0	0	1	0	1	1	0	0	0
River Bend	5	2	1	2	0	5	1	2	2	0
Shoreham	12	10	1	1	0	12	7	5	0	0
St. Lucie 2	12	12	0	0	0	12	10	2	0	0
Susquehanna 2	12	10	2	0	0	12	12	0	0	0
Washington Nuclear 2	12	2	3	4	3	12	8	3	1	0
Waterford 3	12	6	3	3	0	12	11	1	0	0
Wolf Creek	10	3	2	3	2	10	5	5	0	0

Table F.1 (Continued) Unit Performance Benchmark 5-Number Summary Count Data

UNIT NAME	MISCELLANEOUS REPORTS				
	Months	<Median	>Median	Fence	Outlier
Byron 1	12	5	3	2	2
Callaway 1	12	10	1	1	0
Catawba 1	12	8	3	1	0
Diablo Canyon 1	12	8	2	2	0
Diablo Canyon 2	9	7	1	1	0
Fermi 2	10	7	1	1	1
LaSalle 2	12	4	2	4	2
Limerick 1	12	9	0	1	2
McGuire 2	12	11	1	0	0
Millstone 3	2	2	0	0	0
Palo Verde 1	12	9	1	2	0
Palo Verde 2	1	1	0	0	0
River Bend	5	3	1	1	0
Shoreham	12	7	2	2	1
St. Lucie 2	12	12	0	0	0
Susquehanna 2	12	9	2	1	0
Washington Nuclear 2	12	9	2	1	0
Waterford 3	12	7	2	2	1
Wolf Creek	10	8	2	0	0

Table F.1 (Continued) Unit Performance Benchmark 5-Number Summary Count Data

UNIT NAME	TOTALS - EVENTS					TOTALS - EVENTS - PERCENTAGES				
	Months	<Median	>Median	Fence	Outlier	Months	<Median	>Median	Fence	Outlier
Byron 1	58	27	12	13	6	58	46.5517%	20.6897%	22.4138%	10.3448%
Callaway 1	60	27	15	9	9	60	45.0000%	25.0000%	15.0000%	15.0000%
Catawba 1	50	37	7	3	3	50	74.0000%	14.0000%	6.0000%	6.0000%
Diablo Canyon 1	58	42	7	4	6	58	72.4138%	12.0690%	6.8966%	10.3448%
Diablo Canyon 2	37	28	5	3	1	37	75.6757%	13.5135%	8.1081%	2.7027%
Fermi 2	43	24	6	6	7	43	55.8140%	13.9535%	13.9535%	16.2791%
LaSalle 2	60	34	13	7	6	60	56.6667%	21.6667%	11.6667%	10.0000%
Limerick 1	53	33	6	7	7	53	62.2642%	11.3208%	13.2075%	13.2075%
McGuire 2	40	37	2	1	0	40	92.5000%	5.0000%	2.5000%	0.0000%
Millstone 3	6	6	0	0	0	6	100.0000%	0.0000%	0.0000%	0.0000%
Palo Verde 1	51	36	9	3	2	51	70.5882%	17.6471%	5.8824%	3.9216%
Palo Verde 2	3	2	0	1	0	3	66.6667%	0.0000%	33.3333%	0.0000%
River Bend	20	9	5	6	1	20	45.0000%	25.0000%	30.0000%	5.0000%
Shoreham	36	24	8	3	1	36	66.6667%	22.2222%	8.3333%	2.7778%
St. Lucie 2	46	42	3	1	0	46	91.3043%	6.5217%	2.1739%	0.0000%
Susquehanna 2	57	48	8	1	0	57	84.2105%	14.0351%	1.7544%	0.0000%
Washington Nuclear 2	60	32	12	10	6	60	53.3333%	20.0000%	16.6667%	10.0000%
Waterford 3	56	31	7	14	4	56	55.3571%	12.5000%	25.0000%	7.1429%
Wolf Creek	45	25	12	6	2	45	55.5556%	26.6667%	13.3333%	4.4444%