UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

FEB 28 1985

MEMORANDUM FOR: Dennis Kirsch, Director
Division of Reactor Safety and Projects
Region V

FROM: Karl V. Seyfrit, Chief
Reactor Operations Analysis Branch
Office for Analysis and Evaluation
of Operational Data

SUBJECT: EVALUATION OF WNP-2 LERS FOR THE PERIOD
AUGUST 1, 1983 TO JANUARY 31, 1984

The Office for Analysis and Evaluation of Operational Data has assessed the Licensee Event Reports (LERs) submitted under Docket No. 50-397 during the subject period. This has been done in support of the ongoing SALP review of the Washington Public Power Supply System (WPPSS) with regard to their performance as licensee of Washington Nuclear Plant 2 (WNP-2). Our perspective was indicative of that of a BWR system safety engineer who, although knowledgeable is not intimately familiar with the detailed site-specific equipment arrangements and operations.

The licensee submitted at least 137 LERs during the assessment period. For this review, we randomly selected 50 of the LERs from the total submitted in order to provide a statistically significant base for our assessment while limiting the number of LERs reviewed. In order to have at least 90 percent of the 137 LERs acceptable at the 95 percent confidence level, 48 out of the 50 LERs we reviewed would have to be acceptable by our criteria as itemized in the attachment.

From this sample review, we found that in general the LERs typically provided clear descriptions of the cause and nature of the events as well as adequate explanations of the effects on both system function and public safety. In most cases the described corrective actions taken or planned by the licensee were considered to be commensurate with the nature, seriousness, and frequency of the problems found. The attachment provides additional observations from our review of the LERs.

In summary, our review of the licensee's LERs indicates that, the licensee provided adequate descriptions of the events as indicated by the statistical measure stated above and the criteria contained in the attachment.

Furthermore, in general, none of the LERs we reviewed involved what we would consider to be an especially significant event or serious challenge to plant safety.

If you have any questions, please contact either myself or Sal Salah of my staff on FTS 492-4432.

Karl V. Seyfrit

Karl V. Seyfrit, Chief
Reactor Operations Analysis Branch
Office for Analysis and Evaluation
of Operational Data

Attachment:
As stated

cc w/attachment:
R. Auluck, NRR
D. Willett, RV
A. D. Toth, Sr., RV

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Distribution
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DATE	02/27/85	02/27/85	02/27/85				

Attachment

The licensee submitted at least 137 LERs in the assessment period from August 1, 1983 to January 31, 1985. We reviewed 50 randomly selected LERs submitted by the licensee.

The LER review covered the following subjects and the general instructions of NUREG-016. The SALP review is presented with the topic reviewed followed by comments on that topic.

1. Review of LER for completeness

   a) Is the information sufficient to provide a good understanding of the event?

      We found that the LERs provided sufficient data to give clear and adequate descriptions of the occurrences, their direct consequencs, root causes, and where known the corrective actions needed to prevent recurrence.

   b) Were the LERs coded correctly?

      All coded entries reviewed appeared to be correct. However, out of the 50 LERs which were reviewed, the licensee did not specify the following in the coding boxes: (1) the failed component and the component manufacturer in two LERs (84-24 and 84-26) and (2) the failed system, the failed component and the component manufacturer in three LERs (84-33, 84-34 and 84-37).

   c) Was supplementary information provided when needed?

      Most of the LERs reviewed contained supplementary information. The supplementary information provided was clear, concise and adequate.

   d) Were follow-up reports promised and submitted?

      The licensee submitted a follow-up report in every case reviewed where such a commitment was made.

   e) Were similar occurrences properly referenced?

      The licensee appropriately referenced similar prior occurrences as necessary.

2. Multiple Event Reporting in a Single LER

   The licensee did not report any multiple events in a single LER.

3. Prompt Notification Follow-up Reports

   The region issued six PNs during this review period. Two of the PNs issued should have been followed by an LER. Our review indicates that the licensee did issue LERs 84-084 and 84-113 for these two PNs.

In summary, our review indicates that based on the stated criteria, the licensee provided clear and reasonably adequate event reports during the assessment period. No significant deficiencies were found in the LERs reviewed.

AEOD/P501

Feedwater Transient Incidents
in
Westinghouse PWRs

Program Technology Branch
Office for Analysis and Evaluation of Operational Data

Prepared by: Robert L. Dennig
Marcel Harper

July 1985

NOTE: This report documents the results of study by the Office for Analysis and Evaluation of Operational Data. The findings and recommendations do not necessarily represent the position or requirements of the responsible program office nor the Nuclear Regulatory Commission.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

A trends and patterns study was completed of feedwater transients at nuclear power plants. The analysis was limited to the largest single vendor class, Westinghouse PWRs, in order to keep the analysis tractable.

The report covers the period from January 1981 through June 1983 and includes operational experience from 31 nuclear units.

The major findings of the study are:

1) In general, for Westinghouse units the rate of feedwater transients during the first month following an outage is four times higher than the rate during subsequent months. The reason for this substantial difference has not yet been clearly defined.

2) When all Westinghouse units are viewed as a group, Yankee Rowe, Prairie Island 1 and 2, and Point Beach 1 and 2 are outliers due to their low transient rates. Salem 2 is an outlier due to its high transient rate.

3) 2-Loop and Early 4 Loop plants share a transient rate which is a factor of 10 lower than that for 3 Loop and 4 Loop units. The lack of Main Feedwater Pump Faults at 2-Loop units explains part of the difference. The absence of such faults may in turn be due to the use of electric-driven rather than turbine-driven main feedwater pumps.

   Among the 4 Loop units, Cook 1 and Zion 1 are outliers due to their low transient rates, while Salem 2 is again an outlier due to its high transient rate.

4) The age of the unit does not appear to be a factor in explaining the variation in transient rates. Units with more experience do not appear to have significantly fewer transients when the unit design is considered.

5) Main Feedwater Pump Faults are the leading identifiable source of hardware caused feedwater transients in Westinghouse units. These faults occur

primarily at units which have turbine-driven main feedwater pumps. There were 53 main feedwater pump faults, and 39 of these were at 4-loop units. Salem 1 and 2 account for 19 of the 39 Main Feedwater Pump Faults at 4-loop units.

6) At least 25% of all identified feedwater transients were due to operational error.

7) Main Feedwater Regulating Valve Faults comprised the second largest category of component problems leading to feedwater transients. The bulk of the problems were experienced by the 3-Loop units, but all design classes show some incidence. Robinson 2, Surry 1 and Beaver Valley account for 22 of the 43 Main Feedwater Regulating Valve Faults. There is some evidence that age may be a factor for this type of problem.

8) Beaver Valley accounts for 7 of the 11 other (than main feedwater regulating) Valve problems; 6 of these problems are feedwater by pass valve problems.

In addition, the study makes the following recommendations:

1. Since the Commission has concluded that a reduction in the frequency of challenges to plant safety systems should be a prime goal of each licensee, and since Salem 2 is a statistically significant outlier due to its high rate of main feedwater transients, I the procedures and practices at Salem 2 should be reviewed by Region I to identify if improvements are underway or need to be initiated.

2. Further, it's known that the loss of main feedwater is part of a dominant transient sequence in PRAs, and feedwater transients are the major source of unplanned reactor scrams. It has been shown by this study that 3-loop and 4-loop plants have an order of magnitude more feedwater transients than 2-loop and early 4-loop plants, and that the outage rate is 4 times higher in the first month following an outage. Consequently, the specific causes and implications of (a) this wide difference in challenge rate from a single system and (b) the increased challenge rate in the month

following an outage should be further investigated as part of its in-depth study of the causes of reactor scrams.

3. Since personnel errors caused at least 25% of the feedwater transients analyzed in this study; AEOD will also assess, as part of the study discussed above, the causes and characteristics of personnel errors associated with feedwater transients.

1. INTRODUCTION

Feedwater transients comprise the most frequent cause of PWR reactor trips, which in turn are the most frequent class of transients. Thus, feedwater transients as a class frequently cause situations requiring operator response and the operation of backup systems to maintain the unit in a safe condition. In the worst case, loss of main feedwater without prompt recovery is part of a risk-dominant transient sequence. This study, based upon available information, was initiated to characterize the incidence of feedwater transients and, if possible, pinpoint the causes. The inquiry was limited to the largest single vendor class of nuclear units, Westinghouse PWRs, in order to keep the analysis tractable.

This report covers the time period January, 1981 through June, 1983. The following Westinghouse PWRs were licensed for power operation during this entire period and, therefore are included in this study*:

2 Loop	Early 4 Loop	3 Loop	4 Loop
Ginna	Yankee Rowe	San Onofre 1	Indian Pt. 2
Point Beach 1	Haddam Neck	Robinson 2	Indian Pt. 3
Point Beach 2		Turkey Pt. 3	Zion 1
Prairie Is. 1		Turkey Pt. 4	Zion 2
Prairie Is. 2		Surry 1	Cook 1
Kewaunee		Surry 2	Cook 2
		Beaver Valley 1	Salem 1
		Farley 1	Salem 2
		Farley 2	Trojan
		No. Anna 1	Sequoyah 1
		No. Anna 2	Sequoyah 2
			McGuire 1

*V.C. Summer with an initial criticality date of 10/82 was not included in this report.

For the purposes of this report, a feedwater transient is defined as a variation of normal values for process parameters during plant operations, such as:

- o Loss or reduction in feedwater flow
- o Increase in feedwater flow
- o Feedwater flow instability
- o Pressure pulse/surge
- o Steam flow/feed flow mismatch
- o High/low steam generator level

Feedwater transients per se are not reported to the NRC as License Event Reports (LERs). As a result for the time period covered by this report, Gray Book (NUREG-0020, "Licensed Operating Reactors, Status Summary Report Data") was the best source of information on feedwater transients, and almost 90% of the identified instances came from Gray Book. However, Gray Book does not consistently capture power reductions or trips at very low power levels. Consequently, the number of feedwater transients which occurring during the startup phase of operations, as reflected in this report, is known to be low.

2. ANALYSIS OF FEEDWATER TRANSIENT INCIDENCE IN WESTINGHOUSE PWRs

In this section of the report we present the results of our inquiry into the following issues:

1) Do feedwater transients occur at a constant frequency while a unit is critical?

2) Is there variation in the rate of feedwater transients among units?

3) Is there a correlation between the rate of feedwater transients and the basic design class of a unit?

4) Is there a correlation between unit age and the rate of feedwater transients?

Over the 2½ year period studied we identified 224 incidents which met our definition of feedwater transients at the 31 Westinghouse units.

Figure 1 displays the overall pattern of feedwater transients during the period as a function of unit and date. The total number of transients observed at each unit appears in parenthesis to the right of the unit name. Each transient is represented by a dot on a time line (i.e. each dot represents the calendar month in which a transient occurred). The solid bars in Figure 1 represent outages with a duration of one week or greater as identified from Gray Book.

2.1 Distribution of Feedwater Transients Following Outages

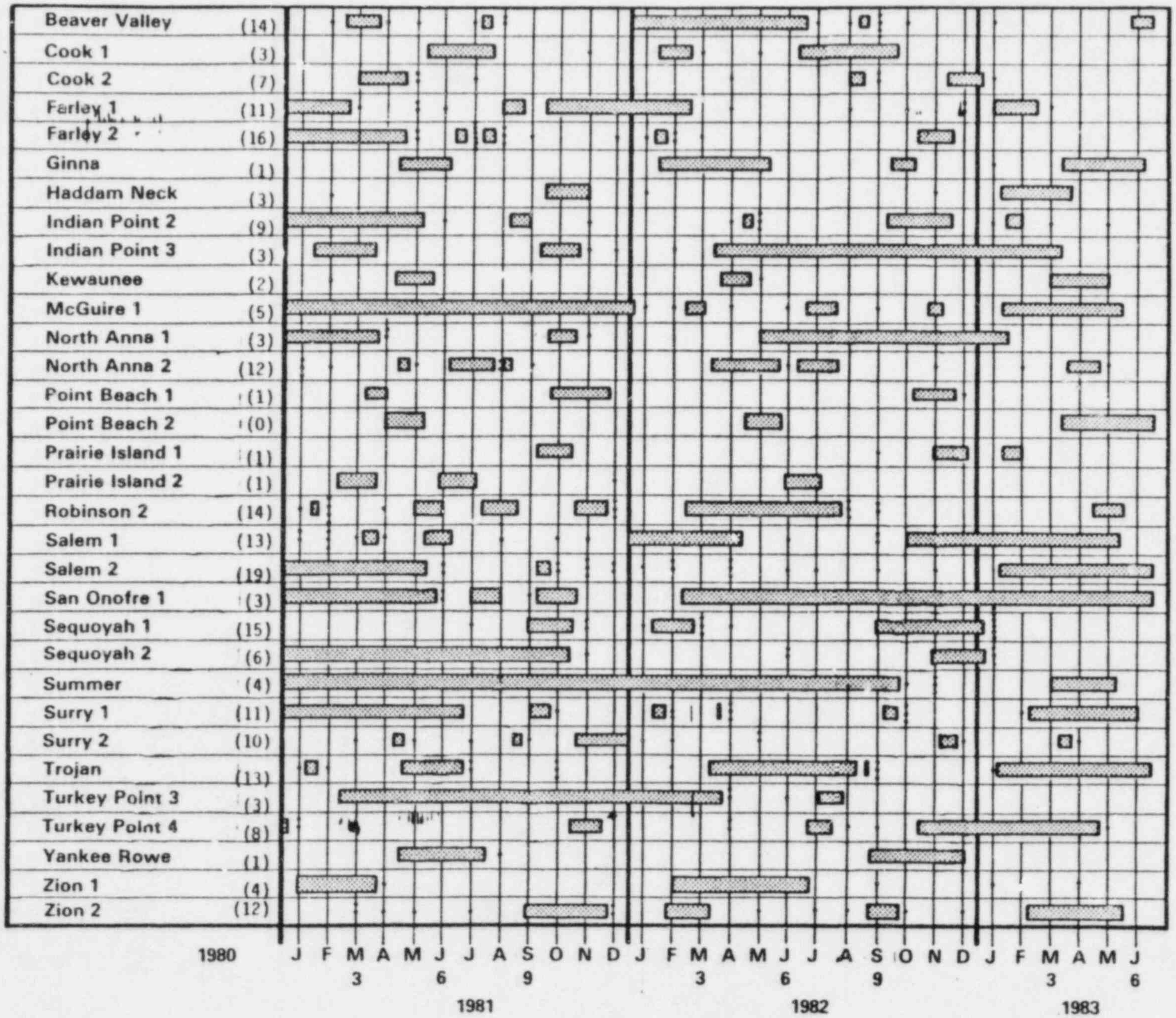
Table 1 shows, by unit, the number of feedwater transient occurrences as a function of time (in months) after an outage lasting at least one week. For example, Beaver Valley 1 had 8 transients within the first month following an outage, 3 within the second month, 0 within the third month, and so on. Across all units over 50% of the transients occurred within the first month following an outage. In over two-thirds of the units, the highest incidence of feedwater transients occurred in the first month after an outage, which indicates that the aggregate behavior is fairly descriptive of the individual units. Thus, there is a strong tendency for feedwater transients to occur shortly (i.e. within a month) following an outage.

Feedwater transients which occurred within one month of an outage were examined to see if the distribution of causes for this group was different from the causes of transients occurring longer after an outage. Table 2 shows the distribution by cause for the two categories.

(Details on how events were assigned to cause categories are provided in Section 3, Causes of Feedwater Transients. Appendix A lists specific events assigned to each category.)

The data in Table 2 indicate a statistically significant difference between the distribution of causes for the first month transients and the distribution for transients occurring later. The difference is due to a decrease in the

Figure 1



• Feedwater Transients

Outages

FEEDWATER TRANSIENTS AT WESTINGHOUSE PLANTS
(1981, 1982, first half of 1983)

Table 1
Feedwater Transient Incidence by Unit and Time After Outage

MONTHS ELAPSED FOLLOWING OUTAGE > 1 WEEK

UNIT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BEAVER VALLEY	8	3	0	1	1	0	0	0	0	0	-	-	-	-	-	-
COOK 1	1	0	1	1	0	0	0	0	0	-	-	-	-	-	-	-
COOK 2	5	0	1	0	0	0	0	0	0	0	0	1	0	0	0	-
FARLEY 1	3	1	2	1	0	1	0	1	0	2	0	0	0	0	0	-
FARLEY 2	14	2	0	0	1	1	0	0	0	0	0	0	0	0	0	-
GINNA	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-
HADDAM NECK	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	-
INDIAN POINT 2	5	2	1	0	0	0	1	0	0	0	0	0	0	0	0	-
INDIAN POINT 3	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	-
KEWAUNEE	1	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-
McGUIRE 1	3	2	1	0	0	0	-	-	-	-	-	-	-	-	-	-
NORTH ANNA 1	3	0	0	0	0	0	-	-	-	-	-	-	-	-	-	-
NORTH ANNA 2	4	1	0	1	0	0	1	0	-	-	-	-	-	-	-	-
POINT BEACH 1	1	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-
POINT BEACH 2	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-
PRAIRIE ISLAND 1	0	0	0	0	0	0	0	0	0	0	1	0	-	-	-	-
PRAIRIE ISLAND 2	0	0	0	0	1	0	0	0	0	0	0	-	-	-	-	-
ROBINSON 2	9	2	1	0	0	0	0	0	0	-	-	-	-	-	-	-
SALEM 1	1	2	0	1	3	0	-	-	-	-	-	-	-	-	-	-
SALEM 2	4	3	2	1	2	0	3	0	1	1	0	1	0	1	0	-
SAN ONOFRE 1	3	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-
SEQUOYAH 1	11	1	1	0	0	0	-	-	-	-	-	-	-	-	-	-
SEQUOYAH 2	4	0	0	0	0	0	0	2	0	0	0	0	-	-	-	-
SURRY 1	6	0	4	0	1	0	0	0	-	-	-	-	-	-	-	-
SURRY 2	5	2	1	0	2	0	0	0	0	0	0	-	-	-	-	-
TROJAN	6	0	0	4	1	0	0	1	0	-	-	-	-	-	-	-
TURKEY POINT 3	2	0	1	0	0	0	0	0	0	0	0	-	-	-	-	-
TURKEY POINT 4	4	1	1	0	2	0	0	0	0	0	-	-	-	-	-	-
YANKEE ROWE	1	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-
ZION 1	1	0	1	0	0	0	1	0	0	1	-	-	-	-	-	-
ZION 2	4	0	1	1	1	-	-	-	-	-	-	-	-	-	-	-
TOTAL	110	24	20	12	15	2	6	4	1	4	1	3	0	1	0	0

Table 2
Cause Distribution Within and Outside One Month Following an Outage

	Within 1st Month	Outside 1st Month
Main Feedwater Pump Faults	18 (17%)	35 (30%)
Main Feedwater Pump Suction Faults	4 (4%)	9 (8%)
Main Feedwater Regulating Valve Faults	23 (21%)	20 (17%)
Other Valve Faults	6 (5%)	5 (4%)
Instrumentation and Control Faults	4 (4%)	7 (6%)
Steam Generator Level Faults	24 (22%)	14 (12%)
Operational Error	29 (27%)	26 (23%)

proportion of Steam Generator Level Faults and an increase in the proportion of Main Feedwater Pump Faults and main feedwater pump suction faults.* As discussed in Section 3, events were assigned to the Steam Generator Level Fault category when further details about the reason for level problems were not provided.

Calculation of failure rates per reactor-month for the months immediately following an outage and failure rates per reactor-month for the subsequent months following an outage reinforces this finding. These rates are tabulated in Table 3.

Table 3
Transient Rates Within and Outside One Month Following an Outage

	Failure Rate in First Month (104 months)	Failure Rate in Subsequent Months (476 months)
Main Feedwater Pump Faults	0.17	0.07
Main Feedwater Pump Suction Faults	0.04	0.02
Main Feedwater Regulating Valve Faults	0.22	0.04
Other Valve Faults	0.06	0.01
Instrumentation and Control Faults	0.04	0.02
Steam Generator Level Faults	0.23	0.03
Operational Error	0.28	0.05
Total	1.04	0.24

*(Reject H_0: No Interaction [Marginal Homogeneity] at 10% level of significance; Pearson Chisquare Statistic = 11.495, P = 0.0742).

It can be seen from this data that the transient rate in the month immediately following an outage is approximately 4 times the transient rates in subsequent months. If we look at the causes of the transients we see that the rate of transients caused by main feedwater pump transients decreases by approximately 2 1/2 times. However, the decrease in some of the other causes is much more pronounced. Transients caused by main feedwater regulating valve faults decrease by 5 1/2 times and transients caused by operator errors also decrease by approximately 5 1/2 times. Transients caused by steam generator level problems decrease by over 7 1/2 times. Although we were unable at this time to identify the reasons for these substantial decreases, it may be because there are more start-ups per month in the month following an outage (due to trips for all causes including feedwater transients) than in subsequent months. We plan to conduct additional studies of this issue in an attempt to identify the root cause of these changes.

Finding

Feedwater transients do not occur at a constant frequency while a unit is critical. The rate of feedwater transients in the month immediately following an outage is approximately 4 times the rate of such transients in subsequent months. The rate in subsequent months is, however, relatively constant. Unfortunately, the reason for this substantial difference in the month immediately following an outage could not be clearly defined.

2.2 Transient Rate as a Function of Unit

Table 4 shows the rate of feedwater transients per reactor critical hour for each unit.*

We performed formal statistical analyses for outliers in the Westinghouse unit population using the HOMOG code developed by INEL. The analysis of the total

*Our finding of the time dependence of the incidence rate makes these average rates over the period rather than point estimates of constant unit-specific rates. However, this time-averaging will not be explicitly called out in the ensuing discussion.

Table 4

Units in Order of Decreasing Transient Rate (Per Thousand Hours)

UNIT	# LOOPS	# TRANSIENTS	CRITICAL HRS	RATE Transient per 1000 Critical Hours
SALEM 2	4	19	13,153	1.44
SEQUOYAH 1	4	15	13,817	1.09
TROJAN	4	13	12,127	1.07
SALEM 1	4	13	12,510	1.04
FARLEY 2	3	16	15,802	1.01
BEAVER VALLEY 1	3	14	14,010	1.00
ROBINSON 2	3	14	14,635	0.95
SURRY 1	3	11	12,629	0.87
FARLEY 1	3	11	13,546	0.81
NORTH ANNA 2	3	12	14,844	0.80
ZION 2	4	12	15,195	0.79
SAN ONOFRE 1	3	3	3,829	0.78
INDIAN POINT 2	4	9	13,909	0.64
TURKEY POINT 4	3	8	13,949	0.57
SEQUOYAH 2	4	6	10,692	0.56
McGUIRE 1	4	5	8,945	0.55
SURRY 2	3	10	18,991	0.52
COOK 2	4	7	16,766	0.41
INDIAN POINT 3	4	3	7,675	0.39
TURKEY POINT 3	3	3	11,514	0.26
NORTH ANNA 1	3	3	11,802	0.25
ZION 1	4	4	15,962	0.25
COOK 1	4	3	16,617	0.18
HADDAM NECK	Early 4	3	18,812	0.15
KEWAUNEE	2	2	18,460	0.10
GINNA	2	1	14,800	0.06
YANKEE ROWE	Early 4	1	17,122	0.05
PRAIRIE ISLAND 2	2	1	18,150	0.05
POINT BEACH 1	2	1	18,432	0.05
PRAIRIE ISLAND 1	2	1	19,831	0.05
POINT BEACH 2	2	0	17,512	0

unit population (i.e. 31 Westinghouse units) indicated that there are statistically significant* differences among the rates for individual units. Further, the following units (Table 5) were flagged as significant outliers when viewed in the context of all plants:

Table 5
Transient Rates As A Function Of Unit

Unit	Rates per 103 hrs Lower Limit	MLE	Upper Limit
All units	0.45**	0.50**	0.56**
Outliers Due To Low Rates			
Yankee Rowe	0.0030	0.058	0.27
Prairie Island 1	0.0026	0.050	0.24
Point Beach 1	0.0028	0.054	0.26
Point Beach 2	0.0	0.0	0.17
Prairie Island 2	0.0028	0.055	0.26
Outliers Due to High Rate			
Salem 2	0.94	1.4	2.1

Finding

There is a significant variation in the rate of feedwater transients among units. Yankee Rowe, Prairie Island 1 and 2, and Point Beach 1 and 2 are outliers due to their low transient rates. Salem 2 is an outlier due to its high transient rate.

2.3 Transient Rate As A Function of Design

When analyzed as a class (See Table 6), the 2 Loop/Early 4 Loop units constitute a statistically homogeneous class with no outliers from the class. Analysis of the remaining units (i.e. 3 and 4 Loop units together) identified Cook 1 and

*Reject homogeneity hypothesis if either a two-sided test based on the most significant outlier or an overall test based on Pearson ChiSquare Statistic is significant at the 10% level.

**Since the population is non-homogeneous, the MLE (Maximum Likelihood Estimate) is for the average of all units, and the Upper and Lower Limits are 90% confidence bounds on the average.

Salem 2 as outliers from the class. Removal of these outliers did not lead to a homogeneous class, although no additional units were indicated as outliers. However, the 3 Loop units by themselves are homogeneous; the 4 Loop units are homogeneous after removal of Cook 1 and Zion 1 as outliers due to their low transient rate, while Salem 2 is an outlier due to its high transient rate. These results are summarized in Table 6.

Table 6
Transient Rates as a Function of Unit Design

Design Class	Outliers	Rates (per 10^3 critical hours) Lower Limit	MLE	Upper Limit
2 Loop/Early 4 Loop	None	0.038	0.070	0.12
3 Loop	None	0.61	0.72	0.85
4 Loop	Outliers/Removed	0.61	0.74	0.89
	Cook 1	0.049	0.18	0.46
	Zion 1	0.086	0.25	0.57
	Salem 2	0.95	1.4	2.1

Subsequently, to try to gain some additional insights into the differences between 2 loop/Early 4 loop and 3 loop/4 loop units, the causes for transients were examined. Table 7 provides a comparison of causes between 2 Loop/Early 4 Loop units and the causes at 3 Loop/4 Loop units. The number of 2 Loop/Early 4 Loop incidents is so small as to preclude formal statistical tests. However, Table 7 shows the notable absence of Main Feedwater Pump Faults from the list of 2 Loop/Early 4 Loop causes, while Main Feedwater Pump Faults comprise the single largest hardware cause for 3 Loop and 4 Loop units. The lack of Main Feedwater Pump Faults at 2-Loop units may be due to the use of electric driven feedwater pumps instead of turbine-driven main feedwater pumps that are used at Farley 1 and 2 and at 4 Loop units (Section 3 shows that main feedwater pump faults occur at a much greater rate at units that have turbine-driven main feedwater pumps).

Table 7
Comparison of Cause Distribution by Design

CAUSE OF TRANSIENT	3-LOOP and 4-LOOP Count, %	2-LOOP, EARLY 4 LOOP Count, %
Main Feedwater Pump Faults	53 (25%)	0 (0%)
Main Feedwater Pump Suction Faults	11 (5%)	2 (20%)
Main Feedwater Regulating Valve Faults	40 (19%)	3 (30%)
Other Valve Faults	11 (5%)	0 (0%)
Instrumentation and Control Faults	11 (5%)	2 (20%)
Steam Generator Level Fault	35 (16%)	1 (10%)
Oper. Error	53 (25%)	2 (20%)
TOTAL	214	10

Finding

There is a correlation between the rate of feedwater transients and design. 2 Loop and Early 4 Loop units share an estimated transient rate which is approximately 10 times lower than that for 3 Loop units and the majority of 4 Loop units.

The 2 Loop/Early 4 Loop units and the 3 Loop units acted as a statistically homogeneous classes, and thus, no outliers for those classes were identified.

Among the 4 Loop units, Salem 2 with an estimated rate of 1.4 per 1000 critical hours is a high outlier; Cook 1 at 0.18 per 1000 hours and Zion 1 at 0.25 per 1000 hours are low outliers.

2.4 Transient Rate as a Function of Unit Age

Finally, the feedwater transient incidents were examined for evidence of an "infant mortality" and/or learning curve effect. To accomplish this we looked at the transient rates from Table 4 as a function of the year the unit entered commercial service.

Table 8 shows the transient rate for each unit as a function of design and age (i.e. year of initial commercial operation). We again tested for homogeneity within each design-age classification to see if the data for the units could be so grouped. No difficulties were encountered for the 2 Loop/Early 4 Loop units. For the 3 Loop units, North Anna 1 proved to be an outlier (due to its low rate) in the 1974-78 category. For the 4 Loop units, Cook 1 was an outlier (due to its low rate) in the 1974-78 category, and Salem 2 was an outlier (due to its high rate) in the 1979-83 category.

We note, then, that age was not the sole reason for the 4-Loop class inhomogeneity problems encountered earlier. When the 3 Loop and 4 Loop outliers were dropped from the analysis*, we found no significant effect due to age; that is, in an analysis that examined the effect of age and design, the variation in transient rate could be adequately explained by design alone.**

Findings

There does not appear to be a correlation between unit age and the rate of feedwater transients. There are significant variations among the transient rates for the Westinghouse units examined. However, the age of the unit does not appear to be an important factor in explaining this variation. When age and design are considered simultaneously, design appears to be more important in explaining transient rate variation. The notion that age is a factor may have arisen because the design with the lowest rate includes the oldest units. However, when we control for unit design, there is no strong evidence for an age effect (i.e. when we look at newer units of a certain design, they do not appear to be statistically different from older units of the same design).

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*We used log linear modeling via multiway contingency table techniques. The analysis was performed with the BMDP-P4F Code.

**Model with design effect only: LRT probability = 0.1492; No reason to reject the model at the 10% level of significance.

Table 8
Transient Rates by Age and Design

	1959-63	1964-68	1969-73	1974-78	1979-83
2 Loop & Early 4 Loop	Yankee Rowe 0.06	Haddam Neck 0.16	Prairie Island 1 0.05 Ginna 0.07 Point Beach 1 0.05 Point Beach 2 0.00	Kewaunee 0.11 Prairie Island 2 0.06	-
3 Loop	-	San Onofre 1 0.78	Robinson 2 0.96 Surry 1 0.87 Surry 2 0.53 Turkey Pt 3 0.26 Turkey Pt 4 0.57	Beaver Valley 1.0 Farley 1 0.81 North Anna 1 0.25	Farley 2 0.01 North Anna 2 0.81
4 Loop	-	-	Zion 1 0.25	Trojan 1.1 Zion 2 0.79 Indian PT 2 0.65 Indian PT 3 0.39 Salem 1 1.04 Cook 1 0.18 Cook 2 0.42	Salem 2 1.4 Sequoyah 1 1.09 Sequoyah 2 0.56 McGuire 1 0.56

3. CAUSES OF FEEDWATER TRANSIENTS

In the preceeding discussion we focused on the incidence of feedwater transients as a function of unit, design and age. Causes were discussed in the context of those patterns. This section will focus on the cause categories themselves for all the units and the entire time period.

The cause information provided in Gray Book was inadequate for definitive root cause analysis. However, we were able to develop broad cause categories which provide some insight into where problems exist and where corrective action would be of the most benefit. The following table summarizes the causes of feedwater transients as determined in this study.

Table 9 Feedwater Transient Causes

Main Feedwater Pump Faults	53	
Main Feedwater Pump Suction Faults	13	
Subtotal - Main Feedwater Pump Problems		66
Operational Error		55
Main Feedwater Regulating Valve Faults	43	
Other Valve Faults	11	
Subtotal - Valve Faults		54
Steam Generator Level Faults		36
Instrumentation and Control Faults		13

3.1 Main Feedwater Pump Faults

A transient was designated as caused by a Main Feedwater Pump Fault if the description cited a pump trip without additional detail, or specified hardware problems associated with the pump, the driver (turbine or motor), or local control or protective instrumentation. A list of the transients assigned to this category is provided in Table A.1 of Appendix A.

Table 10 summarizes Main Feedwater Pump Fault incidence as a function of design (number of loops).

Table 10
Main Feedwater Pump Faults by Design Class

2-Loop/Early 4-Loop	0 events at 8 units
3-Loop	14 events at 7 of 11 units
4-Loop	39 events at 10 of 12 units

The absence of Main Feedwater Pump Faults at 2 Loop/Early 4 Loop units was cited previously as contributing to the overall lower transient rates at these facilities. However, even in the 4-Loop category, there is a wide variation among units. For example, two 4-Loop units, Salem 1 and 2, account for 19 of 39 events. Conversely, Indian Point 3, another 4-loop facility, reported no transients in this cause category.

Further investigation showed a striking correlation between the incidence of Main Feedwater Pump Faults and the type of drive employed. The distribution of events among the different designs as shown in Table 10 is for the most part a reflection of the extent to which turbine drives are employed in each design. Table 11 shows the dominance of turbine-driven main feedwater pumps in this cause category.

3.2 Main Feedwater Pump Suction Faults

Main Feedwater Pump Suction Faults encompass those situations when a main feedwater pump trip was attributed to low suction pressure, without further detail, or when such a trip was attributed to condensate system problems. This class is closely related to the Main Feedwater Pump Fault Category since further detail about what caused a main feedwater pump trip could shift events between the two categories. The total of 13 incidents are listed in Table A.2 of Appendix A. We found no significant patterns in these incidents.

3.3 Personnel Errors

In 55 of 224 cases we felt we had enough information to assign a cause of Personnel Error. As listed in Table A.3 of Appendix A this class includes problems with manual steam generator level control, mispositioned switches, and procedural errors. Clearly, 55 events or 25% is a lower bound on the contribution of Personnel Error to feedwater transient occurrence. In particular, many of the Steam Generator Level Faults are probably due to Personnel Error, but we lack the information needed to say so definitely. Due to the lack of specific data on the nature and cause of the errors, no significant patterns in these incidents were identified.

Table 11
Units by Main Feedwater Pump Driver Type

Electric Drive	Design Class	Events	Turbine Drive	Design Class	Events
Ginna	2/4	0	Farley 1	3	3
Point Beach 1	2/4	0	Farley 2	3	6
Point Beach 2	2/4	0	Indian Point 2	4	4
Prairie Island 1	2/4	0	Indian Point 3	4	0
Prairie Island 2	2/4	0	Zion 1*	4	1
Kewaunee	2/4	0	Zion 2*	4	4
Yankee Rowe	2/4	0			
Haddam Neck	2/4	0	Cook 1	4	1
San Onofre 1	3	0	Cook 2	4	1
Robinson 2	3	1	Salem 1	4	10
Turkey Point 3	3	0	Salem 2	4	9
Turkey Point 4	3	0	Trojan	4	3
Surry 1	3	0	Sequoyah 1	4	2
Surry 2	3	1	Sequoyah 2	4	0
Beaver Valley 1	3	1	McGuire 1	4	4
North Anna 1	3	1			
North Anna 2	3	1			
		5			48

*These units have 2 turbine driven pumps and 1 motor-driven pump.

3.4 Main Feedwater Regulating Valve Faults

Forty-three events at nineteen units were classed as Main Feedwater Regulating Valve Faults. These events include fault modes such as leaking by, slow response, loss of control air, and oscillating. The complete list of events is in Appendix A, Table A.4. Table 12 summarizes the Main Feedwater Regulating Valve Faults by design.

Table 12
Main Feedwater Regulating Valve Faults by Design Class

2 Loop/Early 4 Loop	3 events at 3 of 8 units
3-Loop	30 events at 9 of 11 units
4-Loop	10 events at 7 of 12 units

The concentration of Main Feedwater Regulating Valve Faults in the 3-Loop class is due primarily to three units - Robinson 2 (10 events), Surry 1 (7 events) and Beaver Valley (5 events). Investigation of the particulars of the specific feedwater system designs for these units might provide a reason for the observed concentration. Pending such an investigation, other evidence leads us to speculate that for this particular case age rather than design may be the important determinant: (1) Only 2 of the Main Feedwater Regulating Valve Faults occurred at 3-Loop units in the youngest age classification (entered commercial service 1979-83); (2) the 3-Loop units experiencing most of the problem are in the 1969-73 class, and are older than most of the 4-Loop units, which are showing fewer difficulties.

3.5 Other Valve Faults

Eleven events were classified as Other Valve Faults (Table A.5 of Appendix A). This category contains events which mentioned valve problems but were not specific enough to be classed as Main Feedwater Regulating Valve Faults, and problems with feedwater bypass valves. Six of the eleven events were in fact feedwater bypass valve problems at Beaver Valley 1.

3.6 Steam Generator Level Faults

Steam Generator Level Faults (Table A.6 of Appendix A) and Instrumentation and Control Faults (Table A.7 of Appendix A) are two classifications which were created primarily as a result of lack of information. No more specific cause assignment was possible.

4. SUMMARY OF FINDINGS

1) In general, for Westinghouse units the rate of feedwater transients during the first month following an outage is four times higher than the rate during subsequent months. Unfortunately, the reason for this substantial difference could not be clearly defined.

2) When all Westinghouse units are viewed as a group, Yankee Rowe, Prairie Island 1 and 2, and Point Beach 1 and 2 are outliers due to their low transient rates. Salem 2 is an outlier due to its high transient rate.

3) 2-Loop and Early 4 Loop plants share a transient rate which is a factor of 10 lower than that for 3 Loop and 4 Loop units. The lack of Main Feedwater Pump Faults at 2-Loop units explains part of the difference. The absence of such faults may in turn be due to the use of electric-driven vice turbine-driven main feedwater pumps.

   Among the 4 Loop units, Cook 1 and Zion 1 are outliers due to their low transient rates, while Salem 2 is again an outlier due to its high transient rate.

4) The age of the unit does not appear to be a factor in explaining the variation in transient rates. Units with more experience do not appear to have significantly fewer transients when the unit design is considered.

5) Main Feedwater Pump Faults are the leading identifiable source of hardware caused feedwater transients in Westinghouse units. These

faults occur primarily at units which have turbine-driven main feedwater pumps. There were 53 main feedwater pump faults, and 39 of these were at 4-loop units. Salem 1 and 2 account for 19 of the 39 Main Feedwater Pump Faults at 4-loop units.

6) At least 25% of all identified feedwater transients were due to operational error.

7) Main Feedwater Regulating Valve Faults comprised the second largest category of component problems leading to feedwater transients. The bulk of the problems were experienced by the 3-Loop units, but all design classes show some incidence. Robinson 2, Surry 1 and Beaver Valley account for 22 of the 43 Main Feedwater Regulating Valve Faults. There is some evidence that age may be a factor for this type of problem.

8) Beaver Valley accounts for 7 of the 11 other (than main feedwater regulating) Valve problems; 6 of these are feedwater bypass valve problems.

5. RECOMMENDATIONS

1. Since the Commission has concluded that a reduction in the frequency of challenges to plant safety systems should be a prime goal of each licensee, and since Salem 2 is a statistically significant outlier due to its high rate of main feedwater transients, I the procedures and practices at Salem 2 should be reviewed by Region I to identify if improvements are underway or need to be initiated.

2. Further, it's known that the loss of main feedwater is part of a dominant transient sequence in PRAs, and feedwater transients are the major source of unplanned reactor scrams. It has been shown by this study that 3-loop and 4-loop plants have an order of magnitude more feedwater transients than 2-loop and early 4-loop plants, and that the outage rate is 4 times higher in the first month following an outage. Consequently, the specific causes and implications of (a) this wide difference in challenge rate

from a single system and (b) the increased challenge rate in the month following an outage should be further investigated as part of its in-depth study of the causes of reactor scrams.

3. Since personnel errors caused at least 25% of the feedwater transients analyzed in this study; AEOD will also assess, as part of the study discussed above, the causes and characteristics of personnel errors associated with feedwater transients.

Table A.1
Main Feedwater Pump Faults

	Unit Name	Event Date	Cause
3-Loop	Robinson 2	9/13/82	Faulty switch causing feedwater pumps to trip
	Surry 2	3/21/81	Spurious trip of main feed pump
	Beaver Valley 1	8/27/81	Main feed pump trip
	Farley 1	5/20/81	Both steam generator feed pumps tripped
		8/28/82	SG feed pump tripped - faulty bearing monitor
		3/30/83	Main feed pump discharge valve oper.
	Farley 2	7/27/81	Main feedwater pump control problems
		7/27/81	Main feedwater pump control problems
		9/03/81	Relay in feed pump control-lost feed pump
		2/28/82	Low SG level signal-MFP miniflow cycling
		2/28/82	Low SG level signal-MFP miniflow cycling
		3/30/82	SG feed pump trip
	North Anna 1	11/11/81	Fire on main feedwater pump
	North Anna 2	6/18/82	Loss of feed pump
4-Loop	Zion 1	4/22/83	Transformer failure caused loss of feed pump
	Zion 2	3/05/81	Feedwater pump trip
		5/07/81	Loss of inverter caused loss of feed pumps
		5/16/82	SG Hi level caused by feedwater pump
		8/02/82	Feedwater pump control problems
	Indian Point 2	6/15/81	Oil line rupture on main boiler feed pump
		4/02/82	MBFP erratic governor control system
		5/30/82	Main boiler feed pump trip
		3/13/83	Spurious speed runback on main boiler feed pump
	Cook 1	11/03/81	Main feed pump turbine trip-low oil pressure
	Cook 2	4/01/82	Feed pump trip
	Trojan	9/08/82	Main feed pump trip-faulty pressure switch
		9/17/82	Main feed pump trip - failed proximitor
		1/22/83	Main feed pump trip

Table A.1 (Continued)

	Unit Name	Event Date	Cause
4-Loop (cont.)	Salem-1	1/19/81	Steam generator feed pump overspeed trip
		2/01/81	Steam generator feed pump trip
		2/06/81	Steam generator feed pump trip
		2/11/81	Steam generator feed pump trip
		3/01/81	Steam generator feed pump trip
		8/10/81	Steam generator feed pump trip
		10/17/81	Steam generator feed pump trip
		6/21/82	Steam generator feed pump trip
		{9/08/82	Steam generator feed pump-low level
		9/08/82	Steam generator feed pump trip
	Salem 2	6/27/81	Steam generator feed pump trip
		{10/18/81	Steam generator feed pump trip
		10/22/81	Steam generator feed pump trip
		11/16/81	Steam generator feed pump trip
		12/15/81	Steam generator feed pump trip
		2/19/82	Inverter failed causing SG feed pump trip
		4/17/82	SG feed pump trip - low SG level
		4/21/82	SG feed pump overspeed trip
		11/19/82	SG feed pump caused low SG level
	Sequoyah 1	11/26/81	Low main feed pump turbine cond. vacuum
		1/19/82	Main feed pump trip
	McGuire 1	1/03/82	Switchgear problem caused FWP turbine trip
		4/23/82	Feedwater pump trip - low trip set point
		6/05/82	Loss of feedwater pump-suction transmitter failed
		9/25/82	False low oil level trip of FDWPT

Table A.2
Main Feedwater Pump Suction Faults

	Unit Name	Event Date	Cause
Early 4-Loop	Yankee Rowe	8/20/81	Heater drain pump failure-feed pump trip
	Haddam Neck	11/08/82	Loss of suction-main feed pump trip
3-Loop	Turkey Point 3	4/29/82	Condensate pump failure
	Turkey Point 4	4/23/82	Condensate pump trip - Loss of feed
	Surry 2	1/02/82	Feedwater heater hi level - unit tripped
	North Anna 2	11/30/82	Cavitation of condensate pump, followed by loss of feed pump
4-Loop	Salem 2	11/19/81	Steam generator feed pump trip-low suction pressure
		12/17/81	Steam generator feed pump-low suction pressure trip
		1/14/82	Steam generator feed pump suction pressure decrease
		7/06/82	Steam generator feed pump trip on low suction pressu
	Sequoyah 1	11/06/81	Condensate booster pump and main feed pump turbine tripped
		3/10/82	Loss of suction to main feed pump caused by blown f
	McGuire 1	2/16/82	Condensate booster pump trip

Table A.3
Operational Error

	Unit Name	Event Date	Cause
2-loop	Point Beach 1	12/09/82	Low steam generator trip-manual feed control (3% power; after outage)
	Kewaunee	5/23/82	Transfer of steam generator level control
3-loop	Turkey Point 4	8/12/82	High steam generator level trip-damage to feedwater regulating valve control cable
		9/01/82	Procedural error-closed feedwater regulating valve
	Robinson 2	4/21/81	Personnel error during test
	Surry 1	2/22/82	Low steam generator level during manual feed (after shutdown)
		4/16/82	Low steam generator level while feeding in manual (after shutdown)
	Surry 2	5/05/81	Loss of power caused by testing low steam generator level signal
		2/24/82	Low steam generator level while feeding in manual
		5/15/82	Steam generator high level during manual feed
		12/23/82	High steam generator level in manual feed control (after outage)
		*4/13/83	Low steam generator level; feed/steam flow mismatch
	Beaver Valley 1	9/25/82	Closed bypass feedwater regulating valve
	Farley 1	*3/28/81	Low steam generator level-unit trip (Mode 2) (after shutdown)
		9/08/81	SG level control switch misposition
		4/17/82	Inadvertent trip of feedwater pump
		10/18/82	Inadvertent manual trip of feedwater pump
		12/02/82	Low steam generator level cause by operator error (after shutdown)
	Farley 2	5/23/81	Overfeeding of steam generator
		5/24/81	Overfeeding of steam generator
		8/14/81	Loss of SG feed pump while swapping strainers
		8/27/81	Mispositioned flow switch
		*8/30/81	Steam generator low level during startup
		12/22/81	Loss of SG feed pump during panel test - shorted diode
	North Anna 1	*4/09/81	Steam generator high level-reactor trip (following refueling)
		*4/09/81	Steam generator low level-reactor trip (following refueling)
	North Anna 2	1/07/81	Overfeeding steam generator
		*1/22/81	Low steam generator level-reactor trip
		*2/03/81	Steam generator low level-reactor trip
		*5/20/81	Low steam generator level-reactor trip (after outage)
		8/27/81	Inadvertently tripped breaker
4-Loop	Zion 2	3/11/81	Contractor cut cable to feed pump
		4/03/81	Contractor shorted wire-SG low level
	Indian Point 2	*5/17/82	Feedwater system perturbations-trip
		5/08/83	Inadvertent intro. of gasket into FW pump

Table A.3 (Continued)

	Unit Name	Event Date	Cause
4-Loop (cont.)	Indian Point 3	12/03/81	Manual control of feedwater-trip < 5%
		2/14/82	Loss of condensate pump during repair
	Cook 1	3/05/82	High feedwater flow-manual SG control
		5/20/82	Feedwater flow regulation (using iso valve) failed
	Cook 2	5/30/81	Drop in oil pressure while filling lube oil filter tripped feed pump turbine
		7/11/81	Excess feed rate by operator
		1/27/83	Operator error-low level; steam/feed mismatch
	Trojan	4/20/80	Worker shorted breaker; loss of power caused feed control valves to fail
		2/12/81	Perturbation in feedwater system-valve was opened (after shutdown)
		*{7/17/81	Main feedwater pump trip while valving in
		7/19/81	High level in steam generator tripped main feedwater pump (after shutdown)
		10/12/81	Technician caused transient in main feedwater pump control system
		10/23/81	Trip-steam generator low level-difficulty in manual control (10% power-power reduction)
		2/04/82	Trip-steam generator low level-difficulty in manually controlling level (5% power)
		9/14/82	Main feedwater pump trip-technician caused ground on instrument bus
	Salem 2	6/09/81	Overfeeding of SG by startup personnel
		4/28/82	Sabotage of feed pump
		6/30/82	SG feed pump tripped on low suction pressure associated with placing heater in service
	Sequoyah 2	11/12/81	Low boron level caused auto feed to steam generator during start up
		*6/29/82	Trip-low steam generator level

*Personnel error not indicated in Gray Book course description, but coded as personnel error.

Table A.4
Main Feedwater Regulating Valve Faults

	Unit Name	Event Date	Cause
2-loop	Prairie Island 1	9/05/82	Broken air line on feedwater regulating valve
	Prairie Island 2	12/05/81	Failure of feed regulating valve-broken anchor bolts
	Kewaunee	2/28/81	Loss of control air to feedwater regulating valve
3-loop	Turkey Point 3	4/20/82	Failure of controller of feedwater regulating valve
	Turkey Point 4	4/30/82	Mechanical failure of feedwater regulating valve controller
	Robinson 2	1/10/81	Feedwater regulating valve oscillating; faulty capacitors
		2/01/81	Feedwater regulating valve caused steam-feed flow mismatch
		2/02/81	Feedwater regulating valve closed due to air line blowing off
		2/02/81	Feedwater regulating valve closed does to broken air line
		2/02/81	Feedwater regulating valve oscillating-load reduction
		{12/03/81	Feedwater regulating valve malfunction
		12/07/81	Feedwater regulating valve-high delta P
		{8/21/82	Trip due to feedwater regulating valve malfunction
		8/21/82	Trip due to feedwater regulating valve malfunction
		9/06/82	Solenoid for feedwater regulating valve failed, feedwater regulating valves closed
	Surry 1	10/06/81	Main feedwater regulating valve stuck open
		2/22/82	Leakage past main feed flow control valve
		4/15/82	Feedback arm on main feed flow control valve broke
		4/16/82	Broken feedback arm on main feed control valve
		4/25/82	Main feed flow control valve failed closed
		10/16/82	Feed flow control valve failed to respond quickly
		10/23/82	Feed flow control valve failed closed-feedback arm
	Surry 2	7/18/81	Leakage through main feedwater regulating valve
		5/28/82	Feed flow control valve response was sluggish
	Beaver Valley 1	2/11/81	Main feedwater regulating valve went shut
		5/02/81	Feedwater regulating valve-disconnected actuator and fractured stem
		8/14/81	Main and bypass feedwater reg. valve control problems
		8/26/82	Feedwater regulating valve closed-loss of air pressure
		10/18/82	Control problems with main feedwater regulating valve
	North Anna 2	2/27/83	Control air line to main feedwater regulating valve sheared

Table A.4 (Continued)

	Unit Name	Event Date	Cause
3-loop (cont.)	Farley 1	5/17/81	Loss of instrument air to feedwater regulating valve
		12/02/82	Failure of control card for feedwater regulating valve
	Farley 2	7/11/81	Feedwater regulating valve malfunction
4-loop	Zion 1	1/18/83	Failure of feedwater regulating valve
	Zion 2	12/01/81	Steam generator regulating valve failed
		12/22/81	Steam generator regulating valve failure
	Indian Point 2	1/08/83	Steam generator feedwater regulator malfunction
	Cook 2	5/21/81	Feedwater regulating valve failed-solenoid valve failure
		9/18/82	Feedwater regulating valve failed closed-solenoid valve shorted
		9/20/82	Feedwater regulating valve booster relay problems
	Trojan	10/30/81	Feedwater regulating valve shut-burned out solenoid
	Salem 1	4/29/81	Main feedwater regulating valve malfunction-low steam generator level
	Sequoyah 2	6/24/82	Regulator valve drifted closed-feed isolation

Table A.5
Other Valve Faults

	Unit Name	Event Date	Cause
3-Loop	Turkey Point 4	3/22/81	Valve and motor problems
	Beaver Valley 1	4/15/81	Bypass FW regulating valve control problems
		7/19/81	Bypass FW regulating valve slow response
		7/18/82	Bypass flow control valve problems
		9/11/82	Bypass feedwater control valve slow response
		9/11/82	Bypass feedwater control valve slow response
		9/17/82	Low heater drain tank level-stuck valve
		[illegible]/08/83	Slow response of bypass feedwater reg. valve
	Farley 1	6/30/81	Feed reg. bypass valve failure
	Farley 2	1/08/82	SG oscillation-valve malfunction
	North Anna 2	5/31/83	Feedwater bypass flow control valve

Table A.6
General Steam Generator Level Faults

	Unit Name	Event Date	Cause
2-loop	Ginna	1/17/83	Low steam generator level; steam/feed mismatch
3-Loop	San Onofre 1	6/18/81	Steam/feed flow mismatch
	Robinson 2	12/06/81	Low SG level, steam/feed flow mismatch
		8/15/82	Low level steam generator trip
	Turkey Point 3	6/01/82	SG low level, steam/feed flow mismatch
	Turkey Point 4	1/14/81	SG level protection system trip
		1/15/81	SG level protection system trip
		5/16/83	Hi level in SG - reactor trip
	Surry 2	9/03/81	Low SG level, feed/steam flow mismatch
	Farley 2	7/28/81	SG low level during test
		7/28/81	SG low level during test
	North Anna 2	1/06/81	Low SG level-trip
		8/14/81	SG low level-trip
		9/17/81	SG high level-trip
4-Loop	Zion 1	4/18/81	SG low level trip
		9/30/82	Manual reactor trip due to feedwater problems
	Zion 2	7/30/81	Low SG level - steam/feed mismatch
		7/8/82	Steam/feed flow mismatch
		10/17/82	Low SG level, steam/feed flow mismatch
	Indian Point 2	11/24/81	Steam generator high level
		5/24/82	SG high level
	Salem 1	1/31/81	SG low level
	Salem 2	11/24/81	SG low level
	Sequoyah 1	7/11/81	Low steam generator - low feedwater flow
		3/10/82	Low steam generator level during startup
		3/11/82	Low steam generator level during startup
		3/11/82	Low steam generator level during startup
		1/19/83	Steam generator high level
	Sequoyah 1	1/19/83	Steam generator high level
		1/20/83	Steam/feed flow mismatch
		1/20/83	Steam generator high level
		1/20/83	Steam generator high level
		1/20/83	Steam generator low level
	Sequoyah 2	1/03/83	Low steam generator level during startup
		1/03/83	Low steam generator level during startup
		1/03/83	Low steam generator level during startup

Table A.7
Instrumentation and Control Faults

	Unit Name	Event Date	Cause
Early 4-Loop	Haddam Neck	2/27/81	Control air header fitting separation
		1/20/82	Feed flow transmitter failed
3-Loop	San Onofre 1	6/29/81	Leak in SG feed flow sensing line
		9/03/81	Erratic feedwater control
	Surry 1	10/01/82	Feed control system problems
		2/07/83	Feed control system problems
4-Loop	Indian Point 3	11/22/81	Blockage of instru air - low SG level trip
	Trojan	10/04/81	Control relay failure caused loss of power
	Salem 1	11/20/81	SG control channel failed
	Salem 2	2/09/82	SG level channel erratic
		9/08/82	Instru line blew off feed flow transmitter
	Sequoyah 1	4/21/82	Feed control failed to control in auto
	Zion 2	12/04/82	Trip due to feedwater control problems