AEOD ENGINEERING EVALUATION

UNIT: All Westinghouse Plants
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DATE: December 31, 1984
EVALUATOR/CONTACT: D. Zukor

SUBJECT: FEEDWATER TRANSIENTS DURING STARTUP AT WESTINGHOUSE PLANTS

EVENT DATE(S): January 1, 1983 - December 31, 1983

SUMMARY:

This analysis was performed to determine if Westinghouse designed plants had more scrams due to feedwater transients, particularly during startup, than did the other two PWR vendor designs. The analysis showed that 29% of the PWR scrams in the U.S. during 1983 were due to feedwater transients. One third of the scrams which occurred at Westinghouse plants were due to feedwater transients and fifty-four percent of these occurred during startup; the number of feedwater transients per reactor increased as the number of coolant loops increased.

On a percentage basis, the number of scrams due to feedwater transients was about 10% greater for Westinghouse plants than for CE or B&W plants.

*This document supports ongoing AEOD and NRC activities and does not represent the position or requirements of the responsible NRC program office.

INTRODUCTION

As part of AEOD's continuing review of operating experience, it appeared that Westinghouse-designed plants were experiencing a large number of reactor scrams at low power due to feedwater-related events. This study was initiated to evaluate the number of scrams due to feedwater problems at PWRs and determine if Westinghouse-designed plants are experiencing more frequent events. Operating data for 1983 were used in the study to gain an insight into the performance of Westinghouse designed systems. Scrams are particularly significant at Westinghouse plants since each scram challenges the Auxiliary Feedwater System..

DISCUSSION

Steam Generator Level Control System (SGLCS) Description

The purpose of the SGLCS is to match feedwater flow to steam flow. During automatic operation the SGLCS receives three inputs: one from a channel indicating steam flow, one from a channel indicating feed flow, and one from a channel indicating steam generator(SG) level error. The level channel error signal is generated by comparing a delayed signal indicating the actual SG level from each SG to the level program which is based on first stage turbine pressure and is proportional to power. The level error signal is then manipulated to indicate a flow error which can be combined with the inputs indicating steam flow and feed flow to give a total error. This total error signal determines the position of the feedwater regulating valve.

Below 15% reactor power the automatic system is really controlled by the level signal since steam flow and feed flow are very low. This means that the controller can no longer "anticipate" changes since an actual change in SG level must occur (with a built-in time delay) before the feed regulating valve receives a signal. The slow response of the level controller results in overcompensation and large level oscillations. This frequently results in reactor trips indirectly on "Hi SG level" or directly on "Lo SG level". The same problem can occur during a controlled shutdown although it is far more common during startup. As a result, the feedwater flow is usually controlled manually.

During constant power, level control simply involves matching feed flow to steam flow. During transients the situation becomes more complex. The control system accounts for transients in a number of ways. First, if the actual level deviates much from the desired level, the level error is multiplied by a factor large enough to make level error dominant over flow error. Second, during a load change the delay in the level signal allows the error signal from steam flow-feed flow to increase feedwater flow during a load increase during which there is a volume increase in the SG and decrease feedwater during a load decrease in which the volume shrinks in the SG. This assures that the level control system ignores the temporary effects of shrink and swell.

During manual operation the operator controls the SG level from the control room by using a controller which adjusts the position of the feedwater regulating valve. Control is particularly sensitive at low power levels when sensible nuclear heat starts heating the reactor coolant and when the turbine generator is being loaded. Since, as mentioned above, the automatic system does not "anticipate" changes at low power levels, most operators choose to run in manual mode until the turbine is tied to the grid. They then transfer to automatic control. Trips will occur if steam flow and feed flow are not well matched before the transfer is made.

Part of the problem in controlling feedwater at low power is the size of the main feedwater regulating valve. It is a large valve and a small change in its position results in a large change in feedwater flow. For this reason, some plants have installed a small bypass line with a bypass feedwater control valve around the main feed regulating valve. The bypass valve is controlled by the operator and is used below about 15% reactor power. Many trips still occur when the operator transfers feedwater control from the bypass valve to the main feedwater valve because of the difficulty in accurately positioning the main feedwater regulating valve.

Operating Experience

The data base used for this report was obtained from the Incident Response Center data files for the period January 1, 1983 to December 31, 1983. This data base was chosen because it represents the only source of reactor scrams that are consistently reported for all causes and it was at least partially searchable by computer. The search of the Incident Response Center data indicated that 387 of 582 scrams occurred at U.S. PWRs in 1983. Of these scrams, 113 were due to some type of feedwater transient. The number of feedwater transients occurring at each reactor versus the number of years of commercial operation as of December 1983 is shown in Figure 1. The average number of feedwater transients per PWR is 2.21 as is shown by the solid line. Tables 1 to 3 may be used to determine the reactor associated with each point on the graph.

Figure 1 shows the number of feedwater transients occurring during 1983 versus the number of years of commercial operation as of December 1983.

It should be noted that in some cases more than one scram occurred while the operator was trying to restart the plant.

Surry 1 and Surry 2 show a large number of feedwater transients relative to the age of the plant and the number of reactor coolant loops. No explanation could be found for this difference.

FINDINGS

The findings are summarized in Tables 2 through 7. In general, they indicate the following:

- o The rate of occurrence of feedwater transients is highest for Westinghouse reactors.
- o The two major causes of feedwater transients at Westinghouse and CE plants are operator error and mechanical or electrical problems. The major cause of feedwater transients at B&W plants are electrical and/or mechanical problems.
- o Thirty-four percent of the scrams which occurred at Westinghouse plants were due to feedwater transients compared to 21 percent and 20 percent for CE and B&W respectively.
- o Fifty-four percent of the feedwater transients at Westinghouse plants occurred during startup. This compares to forty-two percent at CE and thirty-three percent at B&W.
- o The feedwater transients that occurred during startup or shutdown and were due to operator error at Westinghouse plants accounted for thirty-eight percent of the feedwater transients. These transients accounted for thirty-two percent of the transients at CE plants and none of the transients at B&W plants.
- o On a per reactor basis, the number of scrams occurring per reactor year was between six and eight for all three PWR vendors.

CONCLUSIONS

It appears that the actual number of scrams due to feedwater transients, on a per reactor basis, is slightly higher at Westinghouse designed plants. This may be attributed to controlling feedwater manually on startups and shutdowns and the fact that the operators get little practice in manual control between shutdowns.

SUGGESTIONS

The data indicated that 113 out of 387 scrams (29%), that occurred at U.S. PWRs in 1983 were due to feedwater transients. This represents a significant number of scrams and may indicate that some improvement is needed in the feedwater control system and/or operator training particularly at plants with a relatively large number of feedwater transient scrams. AEOD is evaluating proposed design or operational changes that will reduce the number of feedwater transients and challenges to safety systems in Westinghouse-designed PWRs.

REFERENCES

Incident Response Center Data Files.

TABLE 1. NUMBER OF FEEDWATER TRANSIENTS OCCURRING AT WESTINGHOUSE REACTORS IN 1983

REACTOR	NUMBER OF FEEDWATER TRANSIENTS	YEARS OF COMMERCIAL OPERATION AS OF 12/83
Yankee Rowe	0	22
San Onofre 1	0	16
Haddam Neck	1	16
Ginna	3	13 3/4
Point Beach 1	0	13
Robinson 2	0	12 3/4
Point Beach 2	1	11
Turkey Point 3	1	11
Surry 1	7	11
Surry 2	7	10 1/2
Turkey Point 4	2	10 1/4
Prairie Island 1	1	10
Zion 1	2	10
Kewaunee	5	9 1/2
Indian Point 2	4	9 1/2
Zion 2	2	9 1/4
Prairie Island 2	0	9
Cook 1	0	8 1/3
Trojan	2	7 1/2
Indian Point 3	2	7 1/3
Beaver Valley 1	5	6 2/3
Salem 1	6	6 1/2
Farley 1	2	6
North Anna 1	1	5 1/2
Cook 2	5	5 1/2
North Anna 2	2	3
Sequoyah 1	3	2 1/2
Farley 2	0	2 1/2
Salem 2	6	2
McGuire 1	3	2
Sequoyah 2	6	1 1/2
Summer	3	<1
McGuire 2	3	<1

*San Onofre 1, Salem 2 and Indian Point 3 have been shut-down for a large part of 1983.

TABLE 2. NUMBER OF FEEDWATER TRANSIENTS OCCURRING AT COMBUSTION ENGINEERING REACTORS IN CY 1983

REACTOR	NUMBER OF FEEDWATER TRANSIENTS	YEARS OF COMMERCIAL OPERATION AS OF 12/83
Palisades	1	12
Maine Yankee	1	11
Fort Calhoun	0	10 1/3
Calvert Cliffs 1	0	8 1/2
Millstone 2	1	8
Saint Lucie 1*	0	7
Calvert Cliffs 2	1	6 2/3
Arkansas Nuclear One 2	1	3 3/4
Saint Lucie 2	3	<1
San Onofre 2	4	<1
San Onofre 3	7	<1

*St. Lucie 1 has been shut down for a large portion of 1983

TABLE 3. NUMBER OF FEEDWATER TRANSIENTS OCCURRING AT BABCOCK & WILCOX REACTORS IN CY 1983

REACTOR	NUMBER OF FEEDWATER TRANSIENTS	YEARS OF COMMERCIAL OPERATION AS OF 12/83
Oconee 1	1	10 1/2
Oconee 2	0	9 1/3
Oconee 3	0	9
Arkansas Nuclear One 1	0	9
Rancho Seco	0	8 2/3
Crystal River 3	4	6 3/4
Davis Besse 1	4	6

TABLE 4. FEEDWATER TRANSIENTS OCCURRING IN CY 1983 BY VENDOR AND NUMBER OF COOLANT LOOPS

VENDOR		FEEDWATER TRANSIENTS AT 2 LOOP REACTORS	FEEDWATER TRANSIENTS AT 3 LOOP REACTORS	FEEDWATER TRANSIENTS AT 4 LOOP REACTORS	TOTAL PER VENDOR
W	Transients	10	30	45	85
	Transients per Reactor	1.67	2.5	3.0	2.58
CE	Transients	18	1	N/A	19
	Transients per Reactor	1.8	1	N/A	1.73
B&W	Transients	9	N/A	N/A	9
	Transients per Reactor	1.29	N/A	N/A	1.29

*Calculations are based on 33 Westinghouse Reactors:
6-2 Loop, 12-3 Loop, 15-4 Loop
11 Combustion Engineering Reactors: 10-2 Loop, 1-3 Loop
7 Babcock & Wilcox Reactors: 7-2 Loop

TABLE 5. FEEDWATER TRANSIENTS GROUPED ACCORDING TO MODE OF OPERATION AND VENDOR

VENDOR	MODE	STARTUP	SHUTDOWN	STARTUP OR SHUTDOWN*	STEADY STATE POWER
W	Transients	46	5	7	27
	Transients per Reactor	1.39	0.15	0.21	0.82
CE	Transients	8	5	2	4
	Transients per Reactor	0.73	0.45	0.18	0.36
B&W	Transients	3	2	2	2
	Transients per Reactor	0.43	0.29	0.29	0.29

*Inadequate information to determine if transient occurred specifically during startup or shutdown. These transients are not included in STARTUP or SHUTDOWN columns.

TABLE 6. FEEDWATER TRANSIENTS GROUPED ACCORDING TO CAUSE AND VENDOR

VENDOR	CAUSE	OPERATOR ERROR	ELECTRICAL OR MECHANICAL [1]	MAINTENANCE	SURVEILLANCE OR TESTING	CONTROL PROBLEM	MANUAL TO AUTO TRANSFER [2]	UNKNOWN
W	Transients	35	27	3	2	8	3	7
	Transients per Reactor	1.06	0.[illegible]	0.09	0.06	0.24	0.09	0.21
CE	Transients	7	5	0	0	3	3	1
	Transients per Reactor	0.64	0.45	0	0	0.27	0.27	0.09
B&W	Transients	0	6	0	0	1	0	2
	Transients per Reactor	0	0.86	0	0	0.14	0	0.29

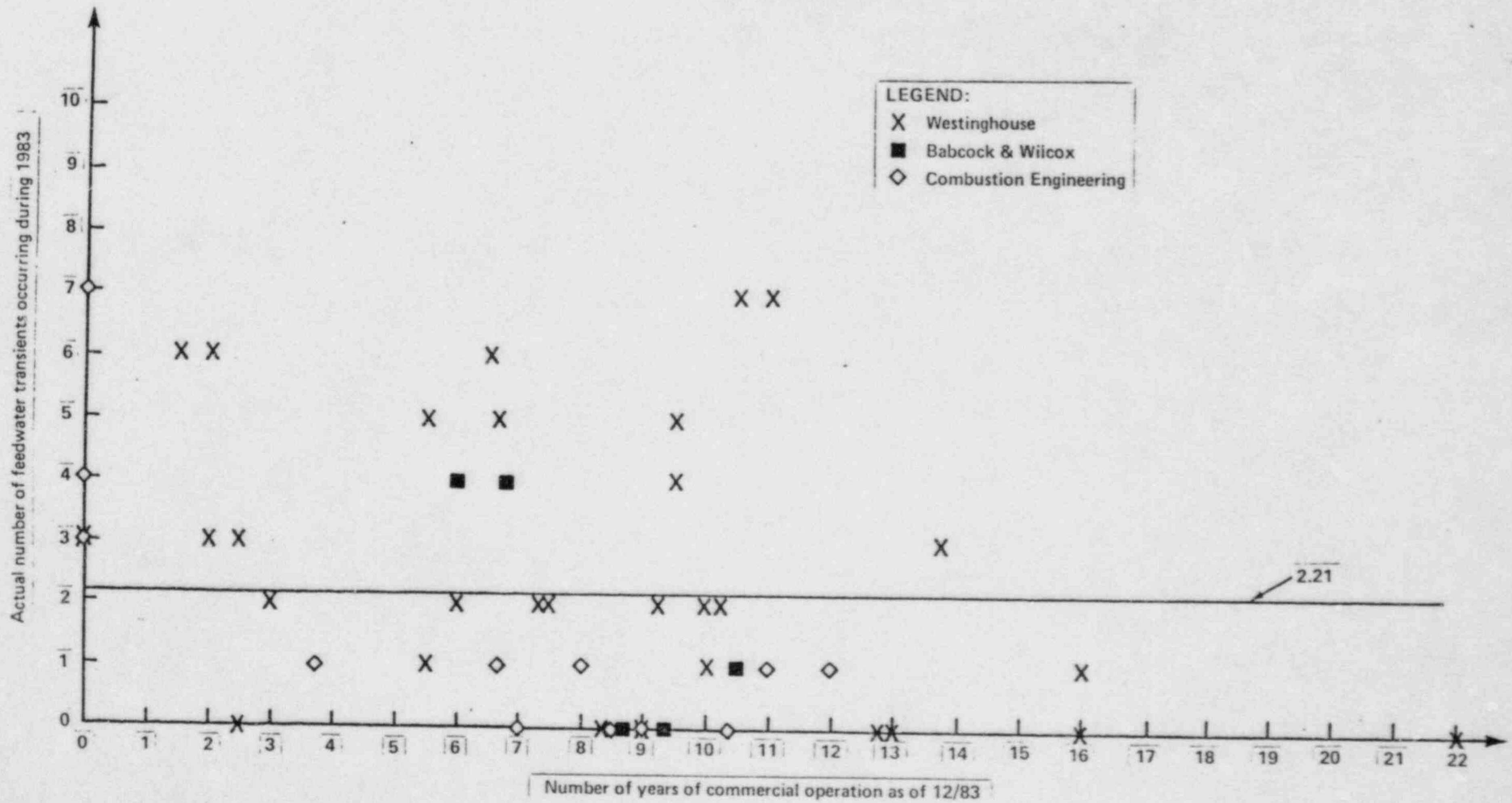
[1] Electrical or mechanical failure caused a feedwater transient.

[2] During transfer to automatic feedwater control a transient and a scram occurred.

TABLE 7. SCRAMS DUE TO FEEDWATER TRANSIENTS

VENDOR		FEEDWATER TRANSIENTS OCCURRING DURING STARTUP OR SHUTDOWN	FEEDWATER TRANSIENTS OCCURRING DURING STARTUP SHUTDOWN AND DUE TO OPERATOR ERROR	ALL FEEDWATER TRANSIENTS	SCRAMS	PERCENTAGE OF SCRAMS DUE TO FEEDWATER TRANSIENTS
W	Transients	58	32	85	252	34
	Transients per Reactor	1.76	0.97	2.58	7.64	--
CE	Transients	15	6	19	89	21
	Transients per Reactor	1.36	0.55	1.73	8.09	--
B&W	Transients	7	0	9	46	20
	Transients per Reactor	1	0	1.29	6.57	--

NOTE: Columns do not add up.



LEGEND:
X Westinghouse
■ Babcock & Wilcox
◇ Combustion Engineering
Actual number of feedwater transients occurring during 1983
Number of years of commercial operation as of 12/83
2.21
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
0 1 2 3 4 5 6 7 8 9 10

FIGURE 1

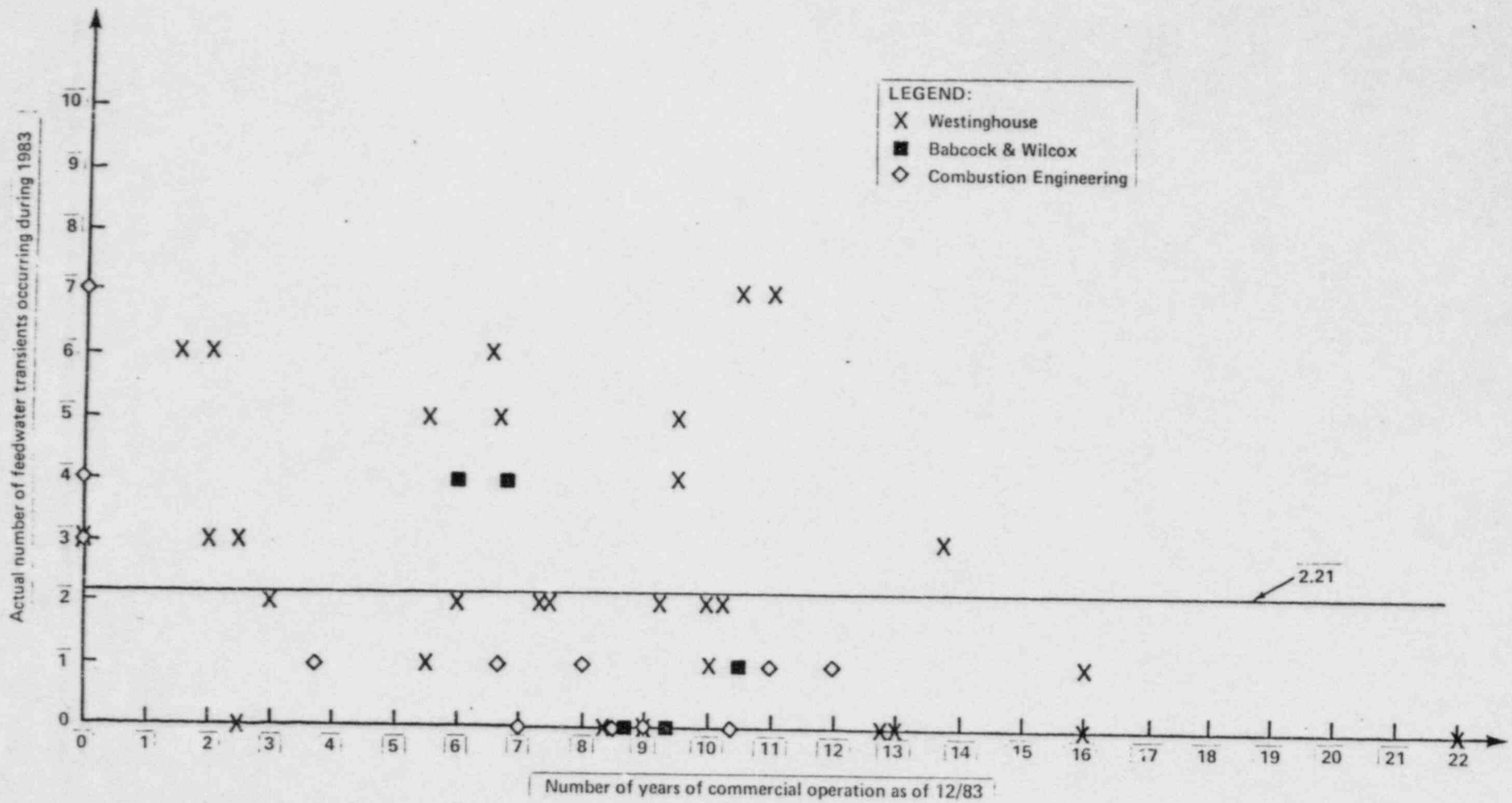

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FIGURE 1