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CP&L

Carolina Power & Light Company
Robinson Nuclear Plant
3581 West Entrance Road
Hartsville SC 29550

10 CFR 50.90

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Serial: RNP-RA/95-0041

APR 06 1995

United States Nuclear Regulatory Commission
ATTENTION: Document Control Desk
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H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23
ADDITIONAL INFORMATION FOR TECHNICAL SPECIFICATIONS CHANGE RELATED TO TURBINE OVERSPEED PROTECTION VALVE TESTING FREQUENCY

Gentlemen:

On November 4, 1994, Carolina Power & Light (CP&L) Company requested a change to the Technical Specifications for the H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2. The requested change will reduce the testing frequency of the turbine overspeed protection valves from monthly to quarterly to implement an enhancement recommended by NRC Generic Letter 93-05, "Line-Item Technical Specification Improvements to Reduce Surveillance Requirements for Testing During Power Operation." The requested change is based upon the findings of WCAP-11525, "Probabilistic Evaluation of Reduction in Turbine Valve Test Frequency," Westinghouse Electric Corporation, June 1987. WCAP-11525 was submitted to the NRC in support of a license amendment request for the Northern States Power Company Prairie Island Nuclear Generating Plant (PINGP), Units No. 1 and 2, Docket Nos. 50-282 and 50-306, dated September 28, 1987. The NRC accepted the methodology described in WCAP-11525 in a Supplemental Safety Evaluation Report for the PINGP dated February 7, 1989.

This letter is in response to questions regarding the change request raised by the NRC during a telephone conversation with CP&L on January 20, 1995.

Enclosure 1 provides an affidavit as required by 10 CFR 50.30(b).

Enclosure 2 provides summarized NRC questions with each CP&L response.

Enclosure 3 provides a copy of Westinghouse Owners Group (WOG) Turbine Valve Test Frequency Subgroup - Final Report, "Update of BB-95/96 Turbine Valve Failure Rates and Effect on Destructive Overspeed Probabilities" (i.e., WOG Final Report). This report bears a copyright on the cover page by Westinghouse Electric Corporation dated 1993. This

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document does not contain proprietary information which must be withheld from public disclosure in accordance with 10 CFR 2.790. However, any copies made of this document for internal use or public disclosure should include the copyright notice on the cover page.

We conclude that HBRSEP is bounded by the assumptions and results of WCAP-11525 and the WOG Final Report, and that quarterly testing of the turbine overspeed valves will maintain the annual frequency of destructive overspeed below the WOG Final Report acceptance criteria of 5.0E-06 per year, utilizing Figure 3, Curve 2 of the WOG Final Report.

Please refer any questions regarding this submittal to Mr. K. R. Jury at (803) 857-1363.

Yours very truly,

R. M. Krich
Manager - Regulatory Affairs

ALG/RES/alg

Enclosures:
1. Affidavit
2. Response to NRC Questions
3. Westinghouse Owners Group (WOG) Turbine Valve Test Frequency Subgroup - Final Report, "Update of BB-95/96 Turbine Valve Failure Rates and Effect on Destructive Overspeed Probabilities"

c: Mr. Max K. Batavia, Chief, Bureau of Radiological Health (SC)
Mr. S. D. Ebneter, Regional Administrator, USNRC, Region II
Ms. B. L. Mozafari, USNRC Project Manager, HBRSEP
Mr. W. T. Orders, USNRC Senior Resident Inspector, HBRSEP
Attorney General (SC)

Enclosure 1

Affidavit

C. S. Hinnant, having been first duly sworn, did depose and say that the information contained in letter RNP-RA/95-0041 is true and correct to the best of his information, knowledge and belief; and the sources of his information are officers, employees, contractors, and agents of Carolina Power & Light Company.

C S Hinnant

Anne H Shepherd

Notary (Seal)

My commission expires: 11/18/96

ENCLOSURE 2

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
NRC DOCKET NO. 50-261/LICENSE NO. DPR-23
ADDITIONAL INFORMATION FOR TECHNICAL SPECIFICATIONS
CHANGE RELATED TO TURBINE OVERSPEED
PROTECTION VALVE TESTING FREQUENCY

RESPONSE TO NRC QUESTIONS

Question 1: The NRC requested that we provide information on how our plant is enveloped by WCAP-11525 and that we provide any differences between our plant design and the assumptions of WCAP-11525. Our response should address the latest update to WCAP-11525.

Answer: H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2, is included in WCAP-11525, "Probabilistic Evaluation of Reduction in Turbine Valve Test Frequency," Westinghouse Electric Corporation, June 1987, and in the current Westinghouse Owners Group (WOG) Turbine Valve Test Frequency Subgroup - Final Report, "Update of BB-95/96 Turbine Valve Failure Rates and Effect on Destructive Overspeed Probabilities" (i.e., WOG Final Report), dated August 6, 1993. Section 5.0 of the WOG Final Report includes HBRSEP in the updated failure rates and destructive overspeed probabilities. HBRSEP is conservative with respect to the WOG Final Report control and stop valve failure rates since no Stop Valve Disk Failures (i.e., Type 1 failures) or Stop Valve Spring Failure and Control Valve Spring Bolt Failures (i.e., Type 4 failures) have occurred, and because HBRSEP has incorporated the recommendations of Westinghouse Operations Maintenance Memoranda (OMM) 108, "Maintenance of Main Stop Valve Spring Seat Retainer Bolt," February 9, 1990, and OMM 121, "BB95 & 96 Control Valve Spring Seat Retainer Bolt," September 6, 1990. With respect to the destructive overspeed probabilities, HBRSEP employs a fully integral rotor construction for the low pressure turbine which "...greatly reduces the chance of formation of stress corrosion cracks with the result that probabilities of missile ejection at design and intermediate overspeed are calculated to be less than 1.0E-06 even for 20 years of operation between inspections."[1]

The subgroup units in the WOG Final Report have experienced a system separation rate of 0.28 per year. The HBRSEP system separation rate over the same period has been one per calendar year. Since the introduction of a turbine generator improvement program in 1989, the system separation rate has been reduced to 0.17 per calendar year. The only system separation in the past six years has been unrelated to the turbine control system.

The HBRSEP turbine system consists of one stop valve and two single seat governor valves on each side of the high pressure turbine, controlled by an Electro-Hydraulic Control (EHC)

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[1]From WOG Final Report, page 6.

system (i.e., WOG Final Report fault tree variation number 4). The assumptions used in the WOG Final Report (i.e., fault tree variation number 3, relatively high solenoid valve failure rates, and 18 to 24 month intervals for control and trip system testing) are very conservative with respect to the actual HBRSEP configuration. The WOG Final Report discusses the inherent bounding assumptions of the fault tree variation used in the analysis (i.e., fault tree variation number 3) compared to the HBRSEP configuration (i.e., fault tree variation number 4). Conservatism with respect to solenoid valve failure rates is discussed in connection with the Public Service Electric & Gas Company Salem Nuclear Generating Station turbine overspeed event in response to Question 3 below.

HBRSEP control and trip system test intervals are scheduled on a refueling outage frequency (i.e., nominally 15 months). During HBRSEP refueling outages, surveillance testing is conducted to completely test the operating functions of the turbine valves and trip circuitry. The turbine equipment is manipulated and repeatedly tripped to ensure that the electrical and mechanical actuation of components is effective. The Local Turbine Control Board and Reactor Turbine Generator Board automatic trip capabilities are tested. Confirmation of valve closure is reviewed, and proper adjustment of valve limit switches is ensured. In addition, each individual turbine overspeed trip solenoid valve is replaced and tested.

Surveillance of stop valve discs is performed on a refueling interval basis. HBRSEP has no installed means of on-line surveillance testing of the stop valve discs. The stop valve surveillance interval is comparable to Curve #1 of Figure 2 of the WOG Final Report. In this figure, a probability of destructive overspeed of 5.6E-06 per year is given for quarterly testing. The actual surveillance interval for stop valve discs is more frequent (i.e., 15 months versus 18 months) than the WOG Final Report assumption in Figure 2, Curve #1. No actual failures of stop valves have been experienced among the 16 subgroup units since the Pacific Gas & Electric Company Diablo Canyon Power Plant event of September 12, 1992. The implementation of OMM 108 at HBRSEP is expected to provide additional assurance that disc failure is not a failure mode. For these reasons, the actual probability of destructive overspeed at HBRSEP is expected to be well below the WOG Final Report acceptance criterion of 5.0E-06 per year.[2]

<u>Question 2:</u> NRC requested information about our operating history.

<u>Answer:</u> HBRSEP has not experienced a failure of a turbine stop or control valve to close upon actual or test demand over its 24 year operating history. The Reheat, Interceptor, Control and Main Stop valves are inspected and maintained in accordance with applicable vendor recommendations, the insurance carrier requirements, and industry standards. The WOG Final Report indicates a failure in the "valve shut" limit switch which failed to clear

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[2]From WOG Final Report, page 5.

during a plant startup. Since the failure involved only valve position instrumentation, this failure was not accounted for in the analyzed data of the WOG Final Report.

Question 3: NRC requested our analysis of the Salem Nuclear Generating Station turbine overspeed event.

Answer: The Salem Nuclear Generating Station experienced electrical and mechanical failures of three turbine overspeed trip solenoid valves. In addition, the Salem Nuclear Generating Station determined that setpoints of the auto stop oil pressure switches were out of calibration due to prolonged operation of the auto stop oil pressure switches with lubrication oil cleanliness exceeding recommended limits. Oil analysis revealed extremely dirty oil which caused the valve on the trip solenoid to bind. Unlike HBRSEP, the Salem Nuclear Generating Station did not replace or independently test the turbine overspeed control solenoid valves during each refueling outage. The binding of the turbine overspeed control solenoid valves which, along with infrequent turbine overspeed control solenoid valve replacement, caused the turbine overspeed control solenoid valves to fail.

The Salem Nuclear Generating Station turbine overspeed event was evaluated for applicability at HBRSEP. Like the Salem Nuclear Generating Station, the HBRSEP turbine has an EHC system. The failure of the turbine control system at the Salem Nuclear Generating Station appeared to be as a direct result of poor maintenance practices.[3] The probability of solenoid valve failures leading to a turbine overspeed event similar to the Salem Nuclear Generating Station event can be reduced by modifying the plant design or by altering maintenance practices. High reliability is achieved at HBRSEP by replacing the solenoid valves on a refueling interval, by the use of maintenance practices specified by our oil cleanliness program, and by maintaining constant communication with the Control Room during valve testing. Both the solenoid valve reliability and the oil cleanliness programs are discussed below.

HBRSEP has a solenoid valve reliability program which (1) tests each turbine overspeed control solenoid valve during each refueling outage to verify that the turbine overspeed control solenoid valves remained operable during the previous cycle, (2) replaces the old turbine overspeed control solenoid valves, and (3) tests the new turbine overspeed control solenoid valves to verify their operability. Replacement of the turbine overspeed control solenoid valves on a refueling cycle is more conservative than the vendor recommendation to replace the valves every five years.

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[3]Refer to NRC Information Notice 91-83, "Solenoid-Operated Valves Failures Resulted in Turbine Overspeed," dated December 20, 1991.

Strict adherence to the vendor's EHC fluid and Turbine Lube Oil system cleanliness criteria has prompted HBRSEP to install additional filtration systems and to conduct complete oil flushes during each outage. HBRSEP has installed an additional filtering system in the EHC system and has installed two additional filter systems in the turbine lube oil system. The EHC filter skid continuously removes any contaminates one (1) micron or larger at a Beta 200 efficiency. The 200 gallon reservoir is completely flushed on a daily basis in contrast to the vendor designed filter system that is operated for only four hours per week and that filters 50% of the reservoir per week. EHC and turbine lube oil samples are taken each month in accordance with Chemistry Procedure (CP)-001, "Chemistry Monitoring Program," and sample results are monitored by our engineering staff. The results of EHC oil analysis indicate a condition of oil cleanliness up to ten times greater than the vendor's recommendation. Further oil filtering capability is provided by additional air side seal oil train filtration on the seal oil skid.

Question 4: NRC requested information about specific vendor recommendations for our turbine.

Answer: The turbine vendor has proposed a modification to the control block and installation of additional valves that provide on-line testing abilities for the turbine overspeed control solenoid valves. The turbine vendor proposes both control block alterations and replacement of the original spool type design valve with a poppet style valve. The poppet valve has the same form, fit and function as the original spool type valve. In the proposed vendor control block alteration, manually operated ball valves provide isolation from the trip header such that on-line testing can occur. An operator performing the monthly test would be expected to hold the spring return lever that isolates the trip fluid while the redundant solenoid valve is energized for the test.

We have concerns with the proposed design modification to provide on-line testing capability because this proposed modification is expected to cause pressure transients which could result in turbine/reactor trips. We have determined, based on industry operating experience, that the failure modes for the turbine overspeed control solenoid valves are either mechanical binding due to foreign particle intrusion or electrical failure due to aging and the high temperature environment where these turbine overspeed control solenoid valves are located.

HBRSEP has a solenoid valve reliability program and an oil cleanliness program as alternatives to incorporating the vendor recommended modification to permit on-line testing of the turbine overspeed control solenoid valves. The HBRSEP solenoid valve reliability program, which replaces the turbine overspeed control solenoid valves each refueling, resolves the aging concern. The HBRSEP oil cleanliness maintenance program results in very clean EHC fluid and turbine lube oil systems which minimizes foreign particle intrusion into the oil systems and minimizes the possibility of mechanical binding of the solenoid valves. We consider that the solenoid valve reliability and oil cleanliness programs in use at HBRSEP are proven methods and are superior to the vendor recommended modification of

the turbine which increases the risk of a turbine trip but does not result in a significant increase in solenoid valve reliability.

In summary, HBRSEP is bounded by the assumptions and results of WCAP-11525 and the WOG Final Report, and quarterly testing of the turbine overspeed valves will maintain the annual frequency of destructive overspeed below the WOG Final Report acceptance criteria of 5.0E-06 per year, utilizing Figure 3, Curve 2 of the WOG Final Report.

ENCLOSURE 3

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
NRC DOCKET NO. 50-261/LICENSE NO. DPR-23
ADDITIONAL INFORMATION FOR TECHNICAL SPECIFICATIONS
CHANGE RELATED TO TURBINE OVERSPEED
PROTECTION VALVE TESTING FREQUENCY

WESTINGHOUSE OWNERS GROUP (WOG) TURBINE VALVE TEST FREQUENCY
SUBGROUP - FINAL REPORT,
"UPDATE OF BB-95/96 TURBINE VALVE FAILURE RATES AND EFFECT ON
DESTRUCTIVE OVERSPEED PROBABILITIES"

UPDATE OF BB-95/96 TURBINE VALVE FAILURE RATES AND EFFECT ON DESTRUCTIVE OVERSPEED PROBABILITIES

August 06, 1993

for
Westinghouse Owners Group
WOG BB-95/96 TVTF Evaluation Subgroup

prepared by:

R. K. Rodibaugh
C. V. Tran

Westinghouse Electric Corporation
Energy Systems Business Unit
P.O. Box 355
Pittsburgh, Pennsylvania 15230

UPDATE OF BB-95/96 TURBINE VALVE FAILURE RATES AND EFFECT ON DESTRUCTIVE OVERSPEED PROBABILITIES

Contents Overview

1.0 INTRODUCTION

In accordance with the program plan for tracking turbine valve failure rates (Reference 1), an evaluation and update of failure rates of BB-95/96 turbine stop and control valves has been completed for the WOG BB-95/96 Turbine Valve Test Frequency Evaluation Subgroup (TVTF subgroup). This report provides the revised failure rates and data tracking curves. The revised failure rates are intended to replace the failure rates that were previously provided in WCAP-11525 (Reference 2). The updated failure rates are based on domestic BB-95/96 turbine valve data collected for the period of January 1986 through May 1992.

The basis for calculating the updated BB-95/96 turbine control and stop valve failure rates has been revised and improved when compared to the basis developed in WCAP-11525. The updated failure data is based on records that begin at a new starting point; January 1986. This date was chosen because an improved process of reporting turbine valve incidents was implemented at that time which has provided better documentation. Data prior to that date, including fossil plant data, has been removed. In accordance with Reference 1, the data tracking effort directs resources to the collection of nuclear plant data. This assures that failure rates can be developed and tracked efficiently without having to deal with a larger population of fossil plants.

The process of reviewing the data has lead to categorizing valve failures in five categories or types, and each failure type has been incorporated into the destructive overspeed fault tree model that is used to evaluate the impact of the revised failure rates. Two new stop valve (SV) and control valve (CV) failure modes have been added to the analysis and data tracking effort: failure of the SV spring and failure of the CV spring bolt. A third failure mode, referred to as "stop valve mechanical damage" in WCAP-11525, has been replaced by the failure "stop valve disc failure." These revised failure modes provide better characterization of the valve incidents that have occurred since 1986.

Revised failure rates are presented in the form of data tracking curves which will be used as a baseline for tracking and evaluating the impact of future valve failures. Probabilities of destructive overspeed are presented in tables and curves which include test intervals for valve freedom of movement in the range of 1 to 6 months.

The impact of the revised failure rates is evaluated through the quantification of the probability of destructive overspeed. This reanalysis has identified failure of the stop valve disc as one of the most important contributors to the overspeed event. Plants in the BB-95/96 TVTF currently do not do on-line surveillance of stop valve discs. Diablo Canyon has installed a diagnostic monitoring system to gather data on the valve vibration signature. The intent of this system is to verify the integrity of the valve disc connection. The impact of additional surveillance of stop valve discs is evaluated, and the destructive overspeed results show a significant reduction in the probability when the additional surveillance is incorporated.

2.0 REVISION OF BB-95/96 VALVE FAILURE RATES

Table 1 summarizes the BB-95/96 control and stop valve failures for the data collection period of January 1, 1986 through May 31, 1992. Valve failure incidents were obtained and validated from two sources: data reports received periodically (usually monthly) at Westinghouse (Source "a" in Table 1) and survey questionnaires completed by the BB-95/96 subgroup plants at the specific request of Westinghouse (Sources "b" and "c"). Continued review of the incidents by Westinghouse and the Subgroup resulted in declassifying some of the incidents as non-valid or non-failures. Table 1 indicates a valid failure by the appearance of a number in the column "No. of Failures." Non-failures are also retained in the table with an explanation of why the incident is not counted as a valid failure.

The third column of Table 1 assigns one of five failure types to the valid failures. This categorization makes it possible to model each failure mode with an hourly failure rate and an applicable time interval. The failures types are standby failures. For standby, failure, the average failure probability is calculated as the failure rate times half of the applicable hourly time interval. The five failure modes and their applicable time intervals are:

Failure Mode	Applicable Time Interval
SV Disc Fails (Type 1)	18 Mo., 24 Mo.
SV Spring Fails (Type 2)	18 Mo., 24 Mo.
SV Fails to Close due to Sticking (Type 3)	1 Mo. to 6 Mo.
CV Spring Bolt Fails (Type 4)	1 Week
CV Fails to Close due to Sticking (Type 5)	1 Mo. to 6 Mo.

The applicable time interval for failure Types 1 and 2 is assumed to be the refueling interval of the associated unit since there is currently no on-line surveillance or inspection related to these faults. The time intervals for Type 3 and 5 faults are based on the assumption that the BB-95/96 subgroup plants will be testing valves for sticking at intervals of 1 to 6 months. Time intervals beyond 6 months are not included for the valve sticking faults because initial analyses, done prior to the finalization of the failure rates, showed that the resultant destructive overspeed probabilities would not meet the acceptance criteria. Failure type 4 (broken spring bolt) is assumed to be surveyed by a weekly visual verification that the spring bolt assembly is intact and not failed. Failure would typically be indicated by finding pieces of the assembly, such as a spring, lying on the floor.

Table 2 summarizes the number of failures by failure type and provides the valve calendar years of service that were the basis of the failure rate calculations. NUREG 002 (Reference 3) was used to determine the total reactor critical hours for each of 24 domestic BB-95/96 units that make up the population for failure data collection. (Sixteen of these 24 units are in the TVTF subgroup). The total number of CV and SV operating hours were determined from these numbers. Reactor critical hours were used because failures that occur during testing prior to placing the turbine on-line are counted if the valve was believed to be operable and steam was present up to the inlet of the stop valve. Average failure rates for the population are calculated as the number of failures divided by the number of valve operating hours and are further multiplied by a factor of 1.2 to account for the possibility of unreported or undocumented incidents. If no failures were reported, the number 0.5 was assumed in the numerator of the calculation of the nominal failure rate.

Comparison of the WCAP-11525 data with the revised failure data shows a major difference in the number of valve calendar years for control valve sticking. This difference can be explained by three factors. First, the WCAP-11525 data spanned a much larger period, beginning in the 1960's and continuing through December 1986. Actually, the WCAP took data from previous fault tree studies that were first performed in the early 1970's. At that time there was a limited amount of BB-95/96 nuclear plant valve operating experience. Therefore fossil plant data (operating hours and failures) was included in the data base. The inclusion of fossil plant data is the second reason why the WCAP-11525 valve calendar years for control valves is much larger. Much of this earlier fossil plant data was derived through the process of expert witness and recall since complete paper records were not available. Nevertheless, these failure estimates were the best possible estimates at the time they were prepared. Third, data from both BB-95/96 and BB-296 (steam chest) control valves was lumped together in the data base for control valve sticking which increased the number of valve calendar years.

The new revised failure rate for control valve sticking is based on a much smaller population of valve calendar years, but the improved paper documentation for this data set results in a higher quality data base and a failure rate in which there is much greater confidence. The fact that no valid sticking failures have reportedly occurred means that the rate may be conservative. Tracking this failure rate to the year 2000 will double the

number of calendar years and will provide evidence of whether the currently calculated failure rate is conservative.

The data provided in WCAP 11525 for stop valve sticking shows 9 failures in 6,700 valve calendar years. The revised data for stop valve sticking shows 0 failures in 462 valve calendar years. The WCAP-11525 number of valve calendar years was affected by the early start date. Fossil data was not included because fossil plants do not have clapper type stop valves. The failure rate for stop valve failure due to sticking is slightly smaller than the WCAP value due to the fact that no sticking incidents occurred during the analysis period.

The failure rate for stop valve disc failure is affected by both the smaller number of valve calendar years and by the fact that failures occurred at the rate of approximately 1 per year during the 1986 through 1992 period. After four disc failures occurred in the period of 1986 through 1988, OMM 108 (Reference 4) was issued to provide the proper procedure for reassembling the disc connection so that it will not loosen from the clapper arm during plant operation. Implementation of OMM 108 may eliminate disc failure as a credible failure mode and, in fact, no new failures have occurred at plants that have been following the OMM. Due to the OMM, disc failure is not expected to continue at the same high rate in the future. However, this failure will be left in the fault tree until enough operating experience accumulates to justify its removal. In the interim, on-line disc surveillance can verify that the discs are not failed during plant operation, and this surveillance evidence results in a lower disc failure probability in the fault tree analysis.

Two new failure modes are identified in the revised analysis: stop valve spring failure and control valve spring bolt failure. Currently there have been no reported incidents of closing spring failure that have been determined to be valid incidents. Four failures of spring bolts occurred. This has called attention to the fact that the control valve spring bolt assembly should be observed during plant walkdowns and verified that it is intact. More importantly, OMM 121 (Reference 5), written after the four failures occurred, provides maintenance advice directed toward preventing spring bolt failure. In view of this, the rate of failure for control valve spring bolts is not expected to continue in the future assuming that the OMM is successfully implemented. However, this failure will be left in the fault tree until sufficient operating experience accumulates to justify its removal.

Figures 1A through 1E are the failure data tracking curves for the five stop and control valve failure modes. The curves show the occurrence of the valid failures that were experienced from 1986 through 1992 versus the time at which they occurred. The horizontal scale begins with year 0, corresponding to January 1, 1986, and ends with Year 7, corresponding to January of 1993. The adjusted failure rate is represented by the slopes solid line in each figure. These lines are the tracking lines that will determine whether new failures, occurring over the next three year period, indicate an increasing or decreasing trend. The slope of the tracking line, calculated on each figure, represents the number of new failures per year that are expected assuming that the 24 units continue to operate in the future.

3.0 ANALYSIS OF BB-95/96 FAILURE RATE IMPACT

The investigation of the impact of the revised BB-95/96 turbine valve failure rates focuses on the probability of destructive overspeed and utilizes the WCAP-11525 methodology and destructive overspeed fault tree. The WCAP-11525 definition of destructive overspeed is: system separation (complete and rapid loss of load on turbine) occurs followed by the failure of one stop and control valve in the same steam path to close. Given that destructive overspeed occurs, all LP rotor types, including rotors with shrunk-on discs and fully integral rotors, are assumed to experience ductile failure of at least one disc at destructive overspeed and ejection of a disc fragment through the turbine casing.

Probabilities of turbine missile ejection at design and intermediate overspeed are not considered in the current analysis. Design and intermediate overspeeds are 120 and 130 percent of rated speed, respectively, for plants with reheat stop and interceptor valves. For plants with LP steam dump systems and no reheat/interceptor valves, design and intermediate overspeeds are approximately 132 and 136 percent. Missile ejection at design or intermediate overspeed can only occur if a crack of sufficient size is present in the LP rotor discs. The fully integral rotor construction greatly reduces the chance of formation of stress corrosion cracks with the result that the probabilities of missile ejection at design and intermediate overspeed are calculated to be less than 1.0E-06 even for 20 years of operation between inspections (Reference 6). All plants in the subgroup with shrunk-on discs (both light disc keyway and heavy disc keyplate types) perform periodic inspections of the LP rotor discs using ultrasonic methods at 5 year intervals or in accordance with Westinghouse recommendations. These inspections detect and monitor crack growth, if any, and eliminate the possibility of operation with a disc crack of critical or near-critical size. The inspection and monitoring of cracks assures that the probability of missile ejection at design or intermediate overspeed in sufficiently small for turbines with shrunk-on discs that the impacts of these events are negligible in comparison to the impact of destructive overspeed. Therefore calculation of the annual probability of destructive overspeed provides a good estimate of the total annual probability of turbine missile ejection.

Destructive overspeed probability results are calculated for a BB-95/96 turbine with four stop valves and four control valves arranged 1-on-1 and an EH control system. The Variation No. 3 destructive overspeed fault tree from WCAP-11525 is used in this analysis. Our evaluations indicate that the fault tree results are applicable to all of the BB-95/96 turbines in the subgroup. This discussed further in Section 4.0 of this report.

The destructive overspeed fault tree from WCAP-11525 was modified to incorporate the new SV and CV failure modes and an updated model of solenoid valve failure and drain system failure. The solenoid valve model incorporates additional common cause failures of the EH trip system 20/ET and 20/OPC solenoid valves which stem from review of overspeed events that occurred at the Salem and St. Lucie stations in 1991 and 1992. Revised solenoid valve failure rates have been incorporated into the model which are

considerably greater than those used in WCAP-11525. A maximum SOV failure rate of 1.0E-05 per hour was selected from NUREG/CR-2815 (Reference 7) because, with the actual occurrence of SOV common mode failures in recent years, a conservative choice of failure rate is prudent at this time. The random failure rate of 1.0E-05 is about 25 times the SOV failure rate in WCAP-11525. The solenoid valve failure rates in the revised model are summarized below:

Failure Mode	Failure Rate (per hour)
20-1/OPC solenoid valve fails to open (random)	1.0E-05
20-2/OPC solenoid valve fails to open (random)	1.0E-05
20/ET solenoid valve fails to open (random)	1.0E-05
20-1/OPC & 20-2/OPC SOVs fail due to common cause	2.0E-06
20-1/OPC & 20/ET SOVs fail due to common cause	2.0E-06
20-2/OPC & 20/ET SOVs fail due to common cause	2.0E-06
20-2/OPC, 20-2/OPC & 20/ET SOVs fail due to common cause	2.0E-06

The 20/ET and 20/OPC solenoid valves are assumed to be tested at refueling. Therefore, the applicable time interval for calculating their failure probabilities is 18 months and 24 months, depending on the current refueling schedule.

The solenoid valves are part of a diverse overspeed protection and trip system for the turbine. Several other trip system component faults are modeled in the fault tree as time-related faults. The assumption was made that test or surveillance of these components occurs during refueling. Actually, some components are exercised as a result of turbine trip for refueling, and some plants may test some trip components, such as the mechanical trip weight, while on-line. Due to different plant-specific practices, the maximum interval of the refueling outage was used in the analysis as the applicable time interval for trip system components. It should be kept in mind that the redundant nature of the trip system components makes it difficult to confirm the operability of some components with turbine trip. (Section 4.0 of this report discusses the applicability of the assumptions related to testing of trip system components.) The following EH trip system and related components are modeled in the destructive overspeed fault tree with the assumption that their operability is confirmed at refueling outages:

- Mechanical overspeed trip mechanism
- Speed detector for overspeed protection controller (OPC)
- 20-1/ & 2/OPC solenoid valves and actuation train
- 20/ET solenoid valve
- Interface valve
- Check valves on ETF lines
- 63/AST pressure switch
- 20/AST solenoid valve and actuation train
- CV dump valve and associated drain line
- Emergency trip fluid lines
- Autostop oil lines

The WCAP-11525 methodology for determining the annual probability included a calculation of the frequency of system separation or loss of load which was based on data. The average frequency of system separation was determined to be 0.5 per year in WCAP-11525. A new average frequency of system separation is determined for the 16 units that make up the BB-95/96 subgroup. The Westinghouse database for initiating events was used in the revised analysis. This database, utilized in developing initiating event frequencies for Westinghouse Individual Plant Examinations (IPEs), includes reactor trip data obtained from Licensee Event Reports (LERs). Data for the generator trip initiating event was obtained from the data base for the period of January 1, 1986 through March 31, 1992. The 16 subgroup units had a total of 21 generator trip incidents during the period. After obtaining the turbine on-line hours for this period, a mean frequency of system separation of 0.28 per year was calculated. This frequency of system separation was used in the analysis of destructive overspeed to produce the annual probabilities of destructive overspeed.

Two cases of destructive overspeed probability are analyzed, an initial case, and a revised case. The initial case assumes that SV disc surveillance occurs only at refueling outages. The revised case considers daily SV disc surveillance and SV disc surveillance performed at the same intervals as the valve freedom of movement tests.

Probabilities of turbine destructive overspeed for the initial case are provided in Table 3. Destructive overspeed probabilities for the revised case are presented in Tables 4A and 4B. The same destructive overspeed probability results are plotted in Figures 2, 3, and 4. Table 3 indicates that for the initial case, stop valve disc failure, control valve sticking, and control valve spring bolt failure dominate the quantification of destructive overspeed. Table 4C indicates that these faults are still dominant. However, the importance factor of the stop valve disc is reduced significantly by the assumed on-line disc surveillance.

4.0 DISCUSSION OF ANALYSIS ASSUMPTIONS AND APPLICABILITY

This section discusses three basic categories of analysis assumptions and the applicability of these assumptions to the plants in the BB-95/96 TVTF subgroup. The three categories of assumptions deal with turbine inlet valve arrangement, control and trip system types, and control and trip system component test intervals.

As illustrated and discussed in WCAP-11525, the two possible arrangements for BB-95/96 inlet valves to the high pressure turbine are one stop valve with two control valves downstream (1-on-2 SV-CV), or one stop valve with one control valve downstream (1-on-1 SV-CV). The two types of control systems are the 300 PSI control oil system and the electrohydraulic (EH) control system.

The simple classification of the BB-95/96 subgroup plants according to HP inlet valve arrangement and control and trip system type is given in the following along with variation

numbers from WCAP-11525:

Variation Number	Plant	HP Valve Arrangement	Control & Trip System Type
1	Turkey Point 3 & 4	1-on-2 SV-CV	300 PSI
2	Indian Point 2	1-on-1 SV-CV	300 PSI
2	Indian Point 3	1-on-1 SV-CV	300 PSI
3	Diablo Canyon 1 & 2	1-on-1 SV-CV	EH
3	Salem 1 & 2	1-on-1 SV-CV	EH
3(1)	Surry 1 & 2	1-on-1 SV-CV	EH
4	Prairie Island 1 & 2	1-on-2 SV-CV	EH
4	Kewaunee	1-on-2 SV-CV	EH
4	Robinson 2	1-on-2 SV-CV	EH
6	Point Beach 1 & 2	1-on-2 SV-CV	EH

(1) Surry 1 & 2 was not in the TVTF Subgroup at the time that WCAP-11525 was prepared.

Given that system separation occurs, each type of HP valve arrangement has four steam paths to the HP turbine, and there are 24 possible combinations of stop valve and control valve failure that result in destructive overspeed (3 SV failure modes X 2 CV failure modes X 4 steam paths). Each plant in the subgroup has clapper-type stop valves and plug-type control valves, so the five SV and CV failure modes are applicable to all. Therefore, from the perspective of basic valve failure rates and the combinations of basic failures that must occur to produce destructive overspeed, the results produced by using the Variation No. 3 fault tree are applicable to all of the turbines in the subgroup.

The use of the Variation No. 3 fault tree means that basic component failures associated with the EH control and overspeed trip system are included in the analysis rather than 300 PSI system basic component failures. Both the EH and 300 PSI systems have similar orders of overspeed protection and trip redundancy and diversity. Both the EH and the 300 PSI systems have a mechanical overspeed trip valve and a 20-AST solenoid valve, either of which dumps the autostop oil and initiates a turbine trip. In the EH system, the dump of autostop oil opens an oil-operated interface valve and a 20/ET solenoid valve, either of which dumps the control and stop valve emergency electrohydraulic trip fluid (ETF). The 300 PSI system has a more developed high pressure autostop oil system that directly causes the stop and control valves to close when the oil is dumped without the use of an interfacing ETF system.

The EH system has two overspeed protection control solenoid dump valves (20-1 OPC and 20-2 OPC), either of which will dump the control ETF line on overspeed, thereby closing the control and interceptor valves. Some, but not all of the 300 PSI systems may have OPC solenoid valves in addition to the auxiliary governor. All 300 PSI systems have an auxiliary governor which performs an overspeed protection function. The auxiliary

governor responds to overspeed or acceleration by rapidly closing the control and interceptor valves.

Although differences exist in the basic control systems for the plants that make up the subgroup, similar redundancy and diversity is provided. The use of relatively high solenoid valve failure rates and solenoid valve common cause factors, as discussed in Section 3.0, assures that the impact of EH control system failures is maximized and conservative. Quantification results and importance factors presented in Tables 3 and 4C indicate that the valve failures are the dominant contributors to destructive overspeed probability and that in comparison, the EH control and trip system failures have a small and negligible impact. Therefore, the destructive overspeed probabilities are applicable and conservative for both the EH and 300 PSI turbines in the subgroup.

Finally, the control and trip system test intervals or applicable time intervals, discussed in Section 3 of this report, were chosen at 18 and 24 months. This is a departure from the WCAP-11525 analysis where shorter trip system surveillance intervals in the range of 1 month to 1 year were used. It is assumed that these time intervals are consistent with or bound the actual test intervals in effect at the subgroup plants. The subgroup plants should verify at least once per refueling outage that the EH or 300 PSI control system components, particularly those associated with overspeed protection and overspeed trip, are operable and in good condition.

5.0 APPLICATION OF RESULTS AND CONCLUSIONS

The updated failure rates and destructive overspeed probabilities presented in this report are applicable to the following BB-95/96 TVTF Subgroup plants:

UTILITY	PLANT
Carolina Power & Light	H. B. Robinson 2
Consolidated Edison Co. of New York	Indian Point 2
Florida Power & Light	Turkey Point 3 & 4
New York Power Authority	Indian Point 3
Northern States Power	Prairie Island 1 & 2
Pacific Gas & Electric	Diablo Canyon 1 & 2
Public Service Electric & Gas	Salem 1 & 2
Virginia Power	Surry 1 & 2
Wisconsin Electric Power	Point Beach 1 & 2
Wisconsin Public Service	Kewaunee

The results presented in this report supersede the previous results in WCAP-11525. TVTF Subgroup plants that currently use WCAP-11525 as a basis for determining

appropriate turbine valve test intervals should use the information provided in this report as the new revised basis. The Figure 2 curves can be used to verify turbine valve test intervals assuming that there is no stop valve disc surveillance. Figure 3 and 4 curves can be utilized to verify suitable turbine valve test intervals assuming that stop on-line valve disc surveillance is incorporated into the turbine's surveillance program. Implementation of disc surveillance provides a significant benefit in that it reduces the probability of destructive overspeed by a factor of two or more depending on the disc surveillance interval selected.

As discussed in Section 3.0, missile ejection at design and intermediate overspeed has not been considered in this report. A review of the definitions of design and intermediate overspeed and the results in Table 8.3-2 of WCAP-11525 was made to determine the effect that the revised failure rates might have on the probabilities of missile ejection at design and intermediate overspeed. The probability of design overspeed of turbines with reheat stop and interceptor valves is affected by the failure rate of the control valves: One or more control valves failing to close following system separation results in design overspeed. WCAP-11525 assumes that plants without reheat stop and interceptor valves reach design overspeed whenever a system separation occurs due to energy input to the low pressure turbine. Therefore, design overspeed probabilities at plants without reheat stop and interceptor valves are not affected by the revised stop valve and control valve failure rates. Intermediate overspeed occurs when a reheat stop valve and interceptor valve in the same steam path fail to close. The probability of this event is unaffected by the revised stop valve and control valve failure rates. WCAP-11525 also identifies intermediate overspeed as resulting from one or more control valves failing to close in conjunction with a failed open stop valve bypass valve in the same steam path. This intermediate overspeed event is affected by the failure rate of the control valves.

Our evaluations indicate that the revised control valve failure rates will not result in any appreciable impact from missile ejection at design and intermediate overspeed. Table 8.3-2 of WCAP-11525 indicates that the reference number rotors 2, 7, and 8 in Table 8.3-2 (Turkey Point and Diablo Canyon) are the only turbines in which design and intermediate overspeed missile probabilities affect the total missile probability in the right hand column of the table. It is our understanding that the reference number 2, 7, and 8 rotors have been replaced or upgraded with heavy disc keyplate rotors that have lower probabilities of missile ejection given design or intermediate overspeed. This should make the results for design and intermediate overspeed insignificant when compared to the destructive overspeed component. Therefore, missile ejection at design and intermediate overspeed is expected to remain an insignificant contributor. A margin can be allowed to safely account for these components of the total missile ejection probability, as discussed in the following.

In verifying the suitability of turbine valve test intervals, it is suggested that the general NRC acceptance criteria for turbine missile ejection (Reference 8) be used. The general acceptance criteria states that the annual probability of turbine missile ejection should not exceed 1.0E-05 per year. To be consistent with the methodology of WCAP-11525 and good engineering judgement, it is suggested that a margin be set aside to allow for

uncertainties and for the fact that a complete analysis of missile ejection at design and intermediate overspeed has not been conducted. The suggested margin amount is 5.0E-06 per year. Our evaluations indicate that the margin of 5.0E-06 per year is adequate to cover the missile ejection probabilities at design and intermediate overspeed. Therefore, the selected turbine valve test interval should be checked against the curves to assure that the probability of destructive overspeed does not exceed 1.0E-05 - 5.0E-06 = 5.0E-06 per year.

A recent NUREG relates to the analysis and scope of this report and is mentioned here so that Subgroup members can consider its findings along with this report in determining suitable turbine valve test intervals. NUREG-1366 (Reference 9), published in December 1992, recommends that "where the turbine manufacturer agrees, the testing interval for turbine valves as part of the turbine overspeed protection system surveillances be extended from weekly and monthly tests to one done quarterly."

6.0 REFERENCES

1. Letter ESBU/WOG-91-168, from J.D. Campbell to Turbine Valve Test Frequency Evaluation Subgroup, including the program plan "Tracking Turbine Valve Failure Rates and Assessing Impact on Existing Analyses," dated November 29, 1990.

2. WCAP-11525, "Probabilistic Evaluation of Reduction in Turbine Valve Test Frequency," prepared by Westinghouse Electric Corp. for the WOG TVTF Subgroup, dated June 1987.

3. NUREG 0020, "Licensed Operating Reactor - Status Summary Report," January 1986 through May 1992.

4. OMM 108, "Maintenance of Main Stop Valves and Reheat Stop Valves," February 9, 1990.

5. OMM 121, "BB95 & 96 Control Valve Spring Seat Retainer Bolt," September 6, 1990.

6. WSTG-4-P, "Analysis of the Probability of the Generation of Missiles from Fully Integral Nuclear Low Pressure Rotors," Westinghouse Steam Turbine Generator Division, dated October 1984.

7. NUREG/CR-2815, "Probabilistic Safety Analysis Procedures Guide," Vol. 1 Rev. 1, Section 5, Appendix C, dated August 1985.

8. Letter from C. E. Rossi of U.S. Nuclear Regulatory Commission to J.A. Martin of Westinghouse Electric Corp., dated February 2, 1987.

9. NUREG-1366, "Improvements to Technical Specifications Surveillance Requirements," by R. Lobel and T.R. Tjader, dated December 1992.

Table 1 (Sheet 1 of 5)

BB 95/96 TURBINE STOP VALVE AND CONTROL VALVE FAILURE DATA
(January 1986 to May 1992)

BB 95/96 TURBINE PLANT	VALVE TYPE	STOP VALVE (SV) AND CONTROL VALVE (CV) FAILURES				
		FAILURE TYPE [1]	FAILURE DESCRIPTION	NO. OF FAILURE	DATE OF FAILURE	COMMENTS
COOPER STATION (A)	SV	--	--	--	--	
	CV	--	--	--	--	
DIABLO CANYON 1 (B1)	SV	--	Didn't close completely. Valve was 1/4" off seat, and there was no steam DP across valve. With steam, valve would have closed.	--	02/01/91	Plant Mode - Turbine trip with steam. Actuator bushing galled due to corrosion and debris. Reliability communication subsequently issued. (Sources a & b) [2]
	CV	--	--	--	--	
DIABLO CANYON 2 (B2)	SV	Type 1	Disc fell off	1	03/23/92	Plant Mode - full load. Failure due to improper assembly. Reliability communication OMM 108 issued prior to this. (Sources a & b) [2]
		--	Slow stroking time during EH testing, due to galling of actuator bushing	--	09/13/91	Plant Mode - unknown. Slow stroking would probably not have prevented the valve from closing, particularly if steam had been present; therefore, not considered a failure. (Source b) [2]
	CV	--	--	--	--	
R.E. GINNA (C)	SV	--	--	--	--	
	CV	--	--	--	--	
HADDAM NECK (D)	SV	--	--	--	--	
	CV	--	--	--	--	
INDIAN POINT 2 (E1)	SV	--	Servomotor piston spring found broken during outage and valve overhaul. Valve had closed properly when unit was shut down for refueling.	--	1989	Plant Mode - outage. (Source b) [2]
	CV	Type 4	Broken spring bolt, springs and upper spring seat dislodged	1	01/13/86	Plant Mode - scheduled outage. Incident attributed to improper assembly. OMM 121 since written. (Source a) [2]

Table 1 (Sheet 2 of 5)

BB 95/96 TURBINE STOP VALVE AND CONTROL VALVE FAILURE DATA

(January 1986 to May 1992)

BB 95/96 TURBINE PLANT	VALVE TYPE	STOP VALVE (SV) AND CONTROL VALVE (CV) FAILURES				
		FAILURE TYPE [1]	FAILURE DESCRIPTION	NO. OF FAILURE	DATE OF FAILURE	COMMENTS
INDIAN POINT 3 (E2)	SV	Type 1	Disc separated from arm	1	1986	Plant Mode - unknown. Limited information. (Source a) [2]
		Type 1	Disc separated from arm	1	10/08/88	Plant Mode - outage. Loss of nut and retaining pins, possibly due to steam erosion of connection. OMM 108 since written. (Source a) [2]
		--	Failed to close	--	10/10/88	Nut loosened from clapper arm. Occurred while unit off-line prior to start. Assumed this was related to the failure on 10/08/88; therefore, not counted. (Source b) [2]
	CV	--	--	--	--	
KEWAUNEE (F)	SV	--	--	--	--	
	CV	--	Found lagging due to failed EHC system card. Valve would have closed in the event of an overspeed trip.	--	04/26/90	Plant Mode - on line valve test. (Source a) [2]
MAINE YANKEE (G)	SV	Type 1	Disc nut loose, pins dislodged.	1	04/29/87	Plant Mode - scheduled outage/steam present Disc hit bottom of body. Failure might not be detected by a valve test. OMM 108 since written. (Source a) [2]
	CV	--	--	--	--	
PALISADES (H)	SV	--	--	--	--	
	CV	Type 4	Bolt and springs dislodged.	1	07/24/86	Plant Mode - outage. Spring bolt stripped out threads in spring housing cover. Failure may be the result of improper assembly. OMM 121 since written. (Source a) [2]

Table 1 (Sheet 3 of 5)

BB 95/96 TURBINE STOP VALVE AND CONTROL VALVE FAILURE DATA

(January 1986 to May 1992)

BB 95/96 TURBINE PLANT	VALVE TYPE	STOP VALVE (SV) AND CONTROL VALVE (CV) FAILURES				
		FAILURE TYPE (1)	FAILURE DESCRIPTION	NO. OF FAILURE	DATE OF FAILURE	COMMENTS
POINT BEACH 1 (I1)	SV	--	--	--	--	
	CV	--	Cross-head sticky operation. Occurred while floor testing valve with valve spring assembly removed	--	04/08/88	Plant Mode - scheduled outage (Source a) (2)
POINT BEACH 2 (I2)	SV	--	--	--	--	
	CV	--	Jerky operation when moved slowly. Based on satisfactory test results, valve would close properly in overspeed trip situation.	--	02/14/88	On-line turbine valve testing, 50% load. (Source b) (2)
	CV	--	Jerky operation (same problem as above)	--	12/14/91	On-line turbine valve testing, 50% load. (Source b) (2)
PRAIRIE ISLAND 1 (J1)	SV	--	--	--	--	
	CV	--	--	--	--	
PRAIRIE ISLAND 2 (J2)	SV	--	--	--	--	
	CV	--	--	--	--	
ROBINSON 2 (K)	SV	--	--	--	--	
	CV	--	Faulty operation. The "valve shut" limit switch failed to clear during startup, with the result that a generator motoring trip occurred.	--	03/22/86	Plant Mode - startup (Source a) (2)
SALEM 1 (L1)	SV	--	--	--	--	
	CV	Type 4	Broken spring bolt, spring assembly flew off	1	12/28/89	Plant Mode - unscheduled outage- steam present. Valve may not have had spring bolt spacer installed. OMM 121 since written. (Source a & b) (2)
SALEM 2 (L2)	SV	--	--	--	--	
	CV	--	--	--	--	
SAN ONOFRE 1 (M)	SV	--	--	--	--	
	CV	--	--	--	--	

Table 1 (Sheet 4 of 5)

BB 95/96 TURBINE STOP VALVE AND CONTROL VALVE FAILURE DATA

(January 1986 to May 1992)

BB 95/96 TURBINE PLANT	VALVE TYPE	STOP VALVE (SV) AND CONTROL VALVE (CV) FAILURES				
		FAILURE TYPE [1]	FAILURE DESCRIPTION	NO. OF FAILURE	DATE OF FAILURE	COMMENTS
SURRY 1 (N1)	SV	--	During prestartup checks, valve failed to close. Cause was incorrect valve lineup in stop valve drain line. After correcting, valve cycled satisfactorily.	--	08/17/88	Plant Mode - outage. Incident was caused by improper lineup of trip pilot drain line to condenser. (Source a) [2]
	CV	--	--	--	--	
SURRY 2 (N2)	SV	Type 1	Disc separated from arm	1	09/10/88	Plant Mode - scheduled outage/steam present. Loss of nut and retaining pins. OMM 108 since written. (Source a) [2]
	CV	--	--	--	--	
TURKEY POINT 3 (O1)	SV	--	--	--	--	
	CV	Type 4	Broken spring bolt	1	03/22/90	Plant Mode - scheduled outage. OMM 121 since written. (Source a) [2]
TURKEY POINT 4 (O2)	SV	--	--	--	--	
	CV	--	--	--	--	
ZION 1 (P1)	SV	Type 1	Disc separated from arm	1	12/11/91	Plant Mode - outage/steam present. Loss of nut and pins, possibly due to improper peening of the pins. OMM 108 written prior to this incident. (Source a) [2]
		--	SV No. 2 failed to close completely during off-line cycling without steam. Trip pilot valve was in off-normal position.	--	01/27/89	Plant Mode - outage. Valve would have closed properly with steam present. (Source a) [2]
		--	SV No. 2 failed to close completely during off-line cycling without steam. Attributed to trip pilot valve which was then replaced.	--	02/04/89	Plant Mode - outage. Valve would have closed properly with steam present. (Source a) [2]
	CV	--	--	--	--	
ZION 2 (P2)	SV	--	--	--	--	
	CV	--	--	--	--	

Table 1 (Sheet 5 of 5)

BB 95/96 TURBINE STOP VALVE AND CONTROL VALVE FAILURE DATA
(January 1986 to May 1992)

Notes:

(1) The valve failure types are:

Type 1: SV Disc Fails
Type 2: SV Spring fails
Type 3: SV Sticks Open
Type 4: CV Spring Bolt Fails
Type 5: CV Sticks Open

(2) The sources of valve failure data are:

Source a: Data collected via periodic reports provided to Westinghouse, such as VISTA field reports, WRITs, and EFARs

Source b: Data provided in response to survey questionnaire transmitted via Westignhouse letter WOG-TVTF-92-12 dated July 31, 1992.

Source c: Failure data confirmation provided in response to questionnaire transmitted via Westignhouse letter WOG-TVTF-93-08 dated April 21, 1993.

Table 2

REVISED TURBINE VALVE FAILURE DATA AND COMPARISON WITH WCAP-11525

Turbine Valve Type[1] and Failure Mode	WCAP-11515 Failure Data (early years through 1986)		Revised Failure Data (January 1986 through May 1992)	
	Number of Failures	Valve Calendar Years of Service	Number of Failures	Valve Calendar Years of Service
SV Disc Fails (Type 1)	2	6,700	6	462[2]
SV Spring Fails (Type 2)	NA	NA	0	462
SV Sticks Open (Type 3)	9	6,700	0	462
CV Spring Bolt Fails (Type 4)	NA	NA	4	616[3]
CV Sticks Open (Type 5)	14	79,200	0	616

Turbine Valve Type[1] and Failure Mode	WCAP-11525 Failure Rate (/Hr)	Jan. 1986 - May 1992 Failure Rate:		Ratio of Revised Failure Rate to WCAP-11525
		Nominal	Adjusted[4]	
SV Disc Fails (Type 1)	7.05E-08	2.06E-06	2.47E-06	35.0
SV Spring Fails (Type 2)	NA	1.71E-07	2.05E-07	--
SV Sticks Open (Type 3)	2.33E-07	1.71E-07	2.05E-07	0.9
CV Spring Bolt Fails (Type 4)	NA	1.02E-06	1.22E-06	--
CV Sticks Open (Type 5)	2.95E-08	1.27E-07	1.53E-07	5.2

Notes:

(1) SV = stop valve (clapper type), CV = control valve (plug type)
(2) Based on 2.917 X 10^6 valve operating hours for all BB-95/96 domestic turbines (24 units, 72 operating valves) during the period of Jan. 1, 1986 through May 31, 1992.
(3) Based on 3.925 X 10^6 valve operating hours (24 units, 96 operating valves)
(4) The nominal mean failure rates are multiplied by a factor of 1.2 to account for possible unreported or undocumented incidents.

Table 3

ANNUAL PROBABILITIES OF BB 95/96 TURBINE DESTRUCTIVE OVERSPEED
Initial Case (1)

Test Interval for Valve Sticking (Failure Types 3 and 5)	ANNUAL PROBABILITIES FOR:		DOMINANT BASIC FAULTS(2) FOR:	
	18 Mo. Surveillance of SV Disc and Trip System Components	24 Mo. Surveillance of SV Disc and Trip System Components	18 Mo. Surveillance Case	24 Mo. Surveillance Case
1 Month	3.19E-06	4.28E-06	A(90.1), B(35.2), C(64.3), D(3.7), E(2.5), F(0.7), G(2.0)	A(89.2), B(35.1), C(64.2), D(3.7), E(2.5), F(0.5), G(2.6)
3 Months	5.57E-06	7.48E-06	A(88.0), B(61.9), C(37.6), D(3.6), E(2.5), F(2.0), G(2.0)	A(88.2), B(61.8), C(37.4), D(3.6), E(2.5), F(1.5), G(2.6)
6 Months	9.32E-06	1.24E-05	A(85.2), B(76.3), C(23.2), D(3.6), E(2.4), F(4.0), G(1.9)	A(86.1), B(76.2), C(23.2), D(3.6), E(2.4), F(3.0), G(2.6)

Notes:

(1) The initial case is based on the current valve failure rates calculated in Table 2 with the muliplication factor of 1.2 applied and SV disc surveillance at refueling outages. The mean system separation frequency of 0.28 per year is used to produce the results. The surveillance interval of 18 months and 24 months are based on the assumption that component operation or integrity is verified at refueling outages.

(2) The seven most dominant faults, based on Fussel-Vesely importance factors, are listed by letter for each case. The factors can range from 0 to 100, with 100 being the most dominant. The listed faults are:

A = Stop valve disc fails or is disconnected from stem
B = Control valve sticks open
C = Control valve spring bolt fails
D = Stop valve spring fails
E = ET fluid line common to SVs and CVs is clogged
F = Stop valve dump valve fails to open
G = Interface valve fails to open

Table 4A

ANNUAL PROBABILITIES OF BB 95/96 TURBINE DESTRUCTIVE OVERSPEED
Revised Case (1)
(Additional SV Disc Surveillance)

(18 Month Surveillance Interval of Turbine Trip System and Other Related Components)

Test Interval for Valve Sticking (Failure Types 3 and 5)	**ANNUAL PROBABILITIES FOR SV DISC SURVEILLANCE (2) INTERVALS OF:**			
	1 Day	**1 Month**	**3 Months**	**6 Months**
1 Month	3.22E-07	4.76E-07	--	--
3 Months	6.78E-07	--	1.49E-06	--
6 Months	1.39E-06	--	--	4.03E-06

Notes:

(1) The revised cases are based on the current valve failure rates calculated in Table 2 with the multiplication factor of 1.2 applied. The mean system separation frequency of 0.28 per year is used to produce the results. Importance factors for dominant basic faults are provided in Table 4C.

(2) It is assumed that stop valve discs are surveyed on or about the same time as the stop valve freedom of movement tests. Surveillance should verify that the discs are connected and capable of seating properly if a trip occurs. Results for daily surveillance of stop valve discs are also provided.

Table 4B

ANNUAL PROBABILITIES OF BB 95/96 TURBINE DESTRUCTIVE OVERSPEED
Revised Case (1)
(Additional SV Disc Surveillance)

(24 Month Surveillance Interval of Turbine Trip System and Other Related Components)

Test Interval for Valve Sticking (Failure Types 3 and 5)	ANNUAL PROBABILITIES FOR SV DISC SURVEILLANCE(2) INTERVALS OF:			
	1 Day	**1 Month**	**3 Months**	**6 Months**
1 Month	4.45E-07	6.00E-07	--	--
3 Months	8.88E-07	--	1.70E-06	--
6 Months	1.74E-06	--	--	4.37E-06

Notes:

(1) The revised cases are based on the current valve failure rates calculated in Table 2 with the multiplication factor of 1.2 applied. The mean system separation frequency of 0.28 per year is used to produce the results.

(2) It is assumed that stop valve discs are surveyed on or about the same time as the stop valve freedom of movement tests. Surveillance should verify that the discs are connected and capable of seating properly if a trip occurs. Results for daily surveillance of stop valve discs are also provided.

Table 4C

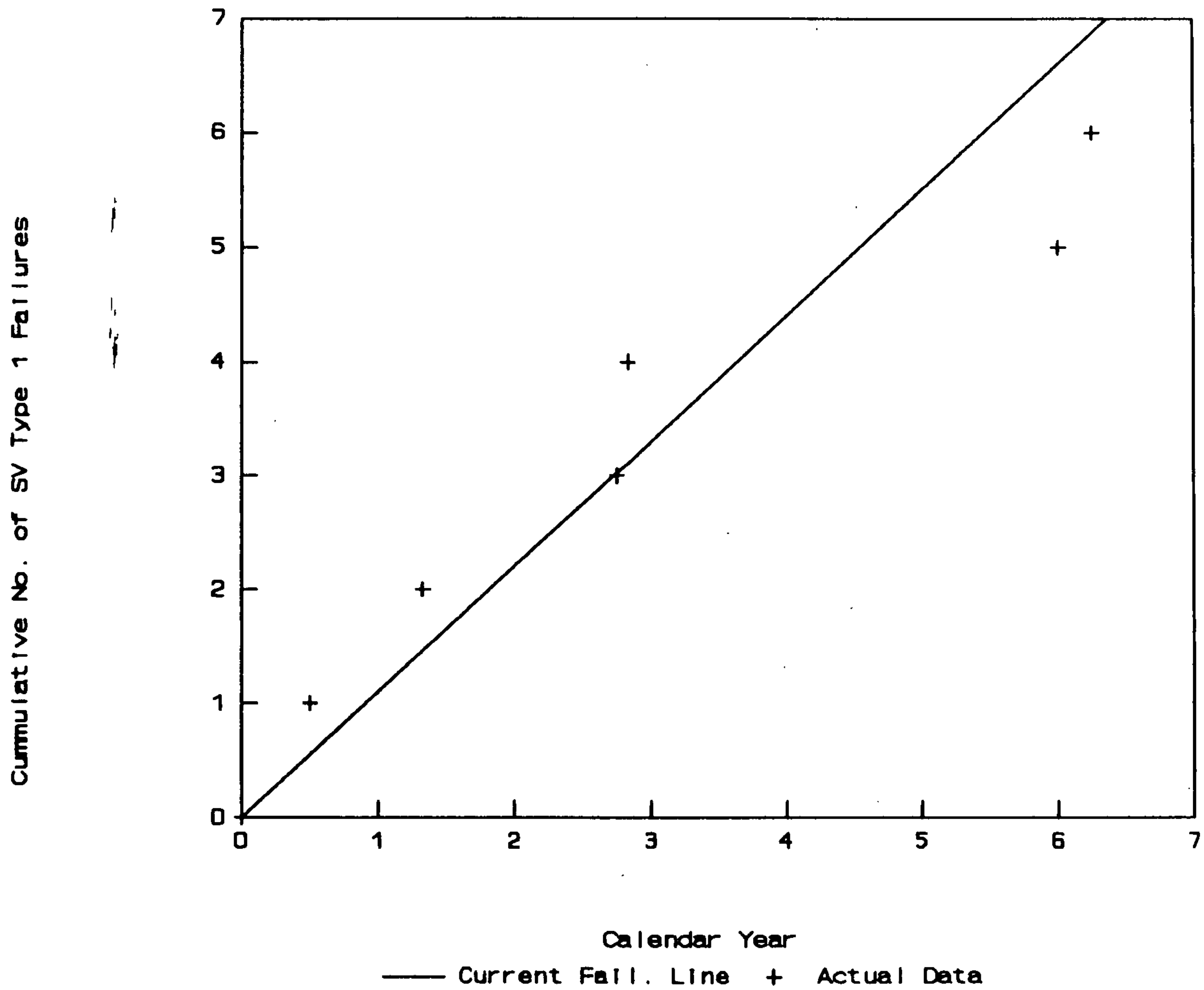
IMPORTANCE FACTORS FOR REVISED CASE
(Corresponding to the Revised Case Table 4A)

Test Interval for Valve Sticking (Failure Types 3 and 5)	IMPORTANCE FACTORS (1) FOR SV DISC SURVEILLANCE INTERVALS OF:			
	1 Day	1 Month	3 Months	6 Months
1 Month	A(1.6), B(34.2), C(63.3), D(37.1), E(25.9), F(6.9), G(19.3), H(4.1), I(10.9)	A(33.5), B(34.6), C(63.8), D(25.1), E(17.0), F(4.6), G(13.0), H(2.8), I(7.4)	--	--
3 Months	A(1.6), B(60.7), C(36.9), D(30.1), E(20.5), F(16.8), G(16.2), H(10.1), I(8.9)	--	A(55.1), B(61.6), C(37.4), D(13.7), E(9.3), F(7.7), G(7.4), H(4.6), I(4.0)	--
6 Months	A(1.0), B(75.0), C(22.8), D(23.8), E(16.1), F(26.5), G(12.8), H(15.8), I(7.0)	--	--	A(65.8), B(76.0), C(23.2), D(8.2), E(5.6), F(9.2), G(4.4), H(5.4), I(2.4)

Notes:

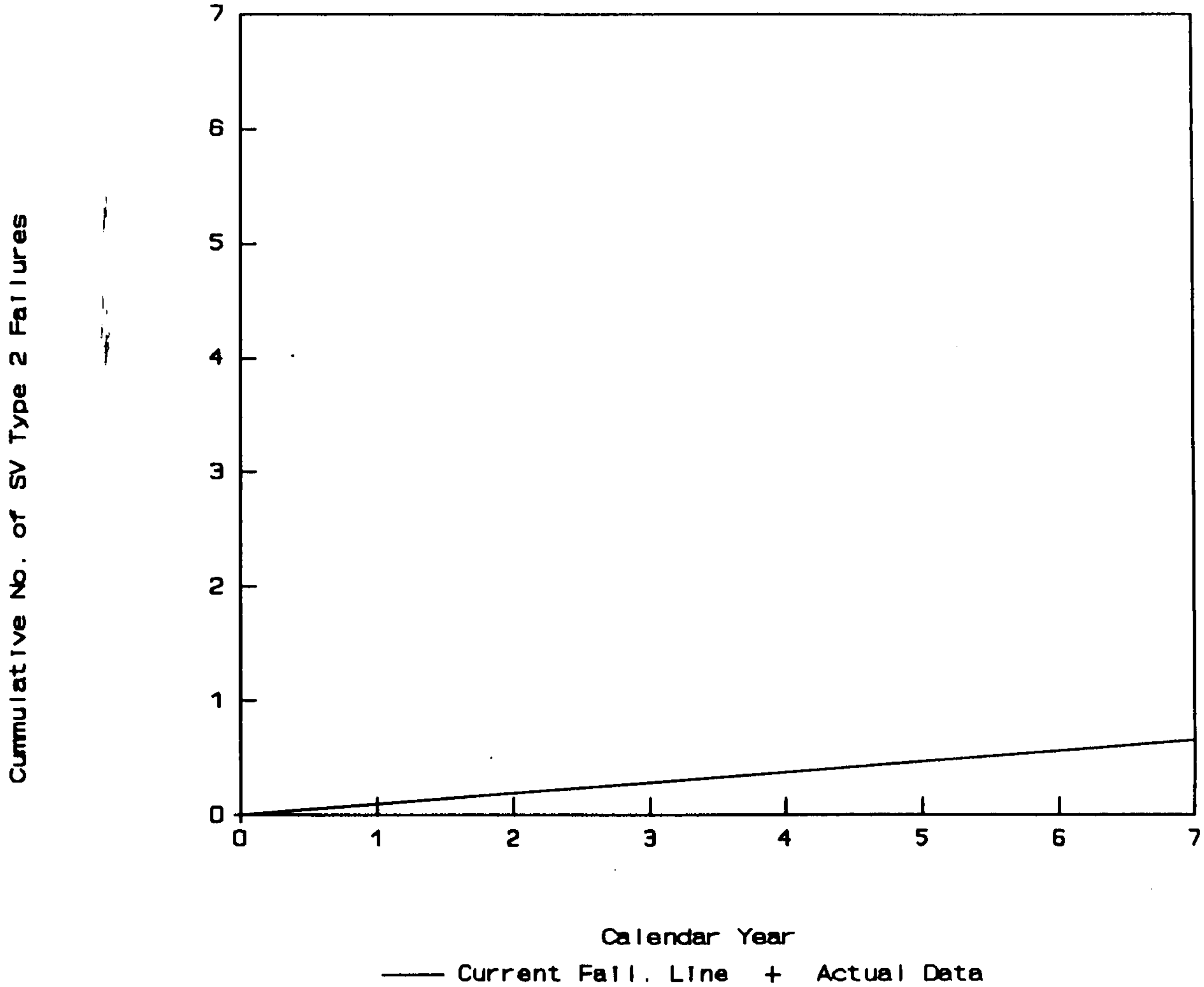
(1) The nine most dominant faults, based on Fussel-Vesely importance factors, are listed by letter for each case. The factors can range from 0 to 100, with 100 being the most dominant. The listed faults are:

A = Stop valve disc fails or is disconnected from stem
B = Control valve sticks open
C = Control valve spring bolt fails
D = Stop valve spring fails
E = ET fluid line common to SVs and CVs is clogged
F = Stop valve dump valve fails to open
G = Interface valve fails to open
H = Stop Valve Sticks Open
I = 20/ET solenoid valve fails to open



Adjusted SV Type 1 Failure Rate	=	2.47E-06/hr
Slope of Current Failure Line	=	[(adjusted SV Type 1 F.R.) * (operating hours)] / (calendar years)
	=	[(2.47E-06/hr) * (2.917E-06 hrs)] / (6.42 cal. yrs) = 1.1 fail./cal. yr.

Figure 1A - TRACKING BB-95/96 STOP VALVE (SV) TYPE 1 FAILURES

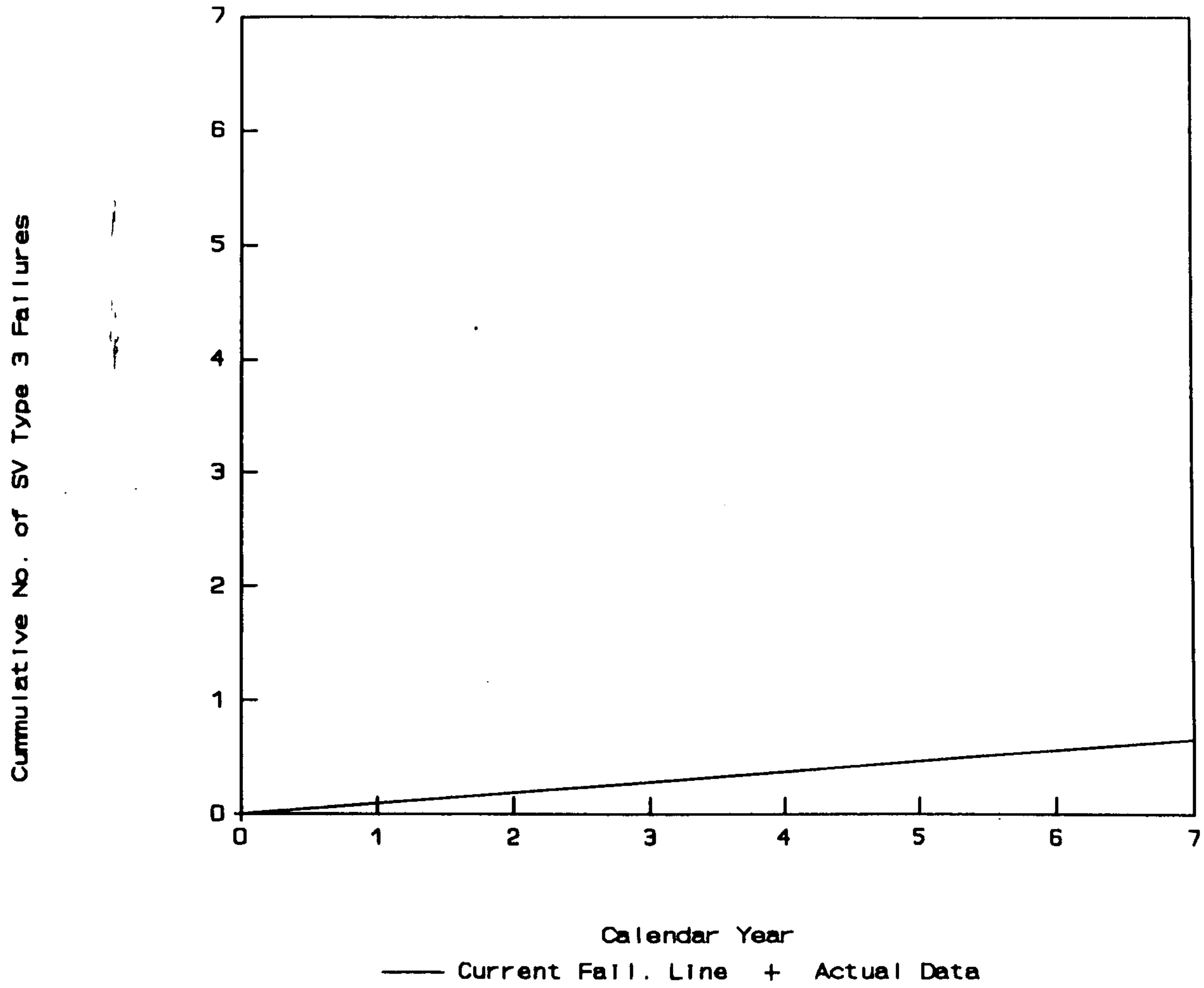


Adjusted SV Type 2 Failure Rate = 2.05E-07/hr

Slope of Current Failure Line = [(adjusted SV Type 2 F.R.) * (operating hours)] / (calendar years)

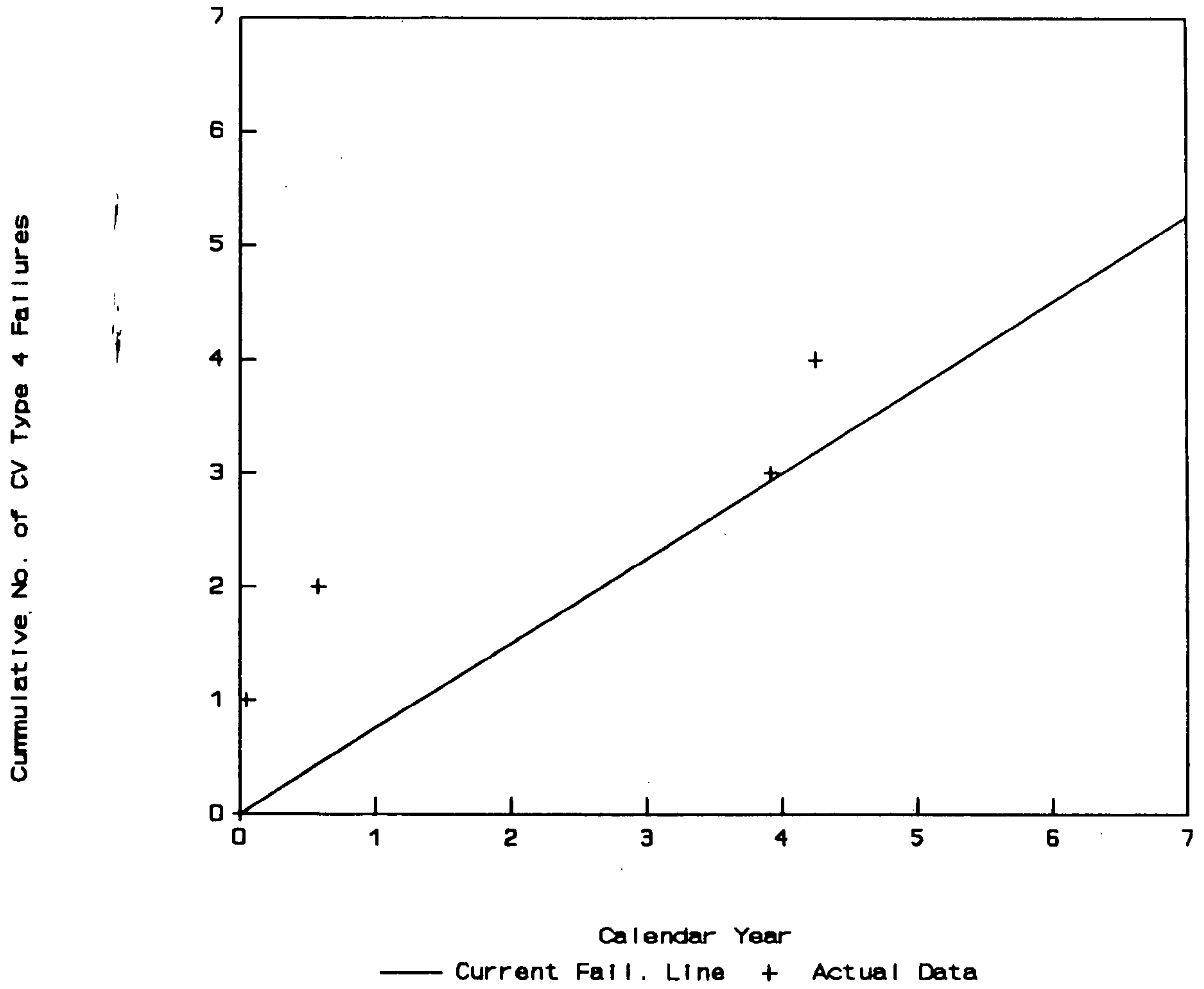
= [(2.05E-07/hr) * (2.917E-06 hrs)] / (6.42 cal. yrs) = 0.093 fail./cal. yr.

Figure 1B - TRACKING BB-95/96 STOP VALVE (SV) TYPE 2 FAILURES



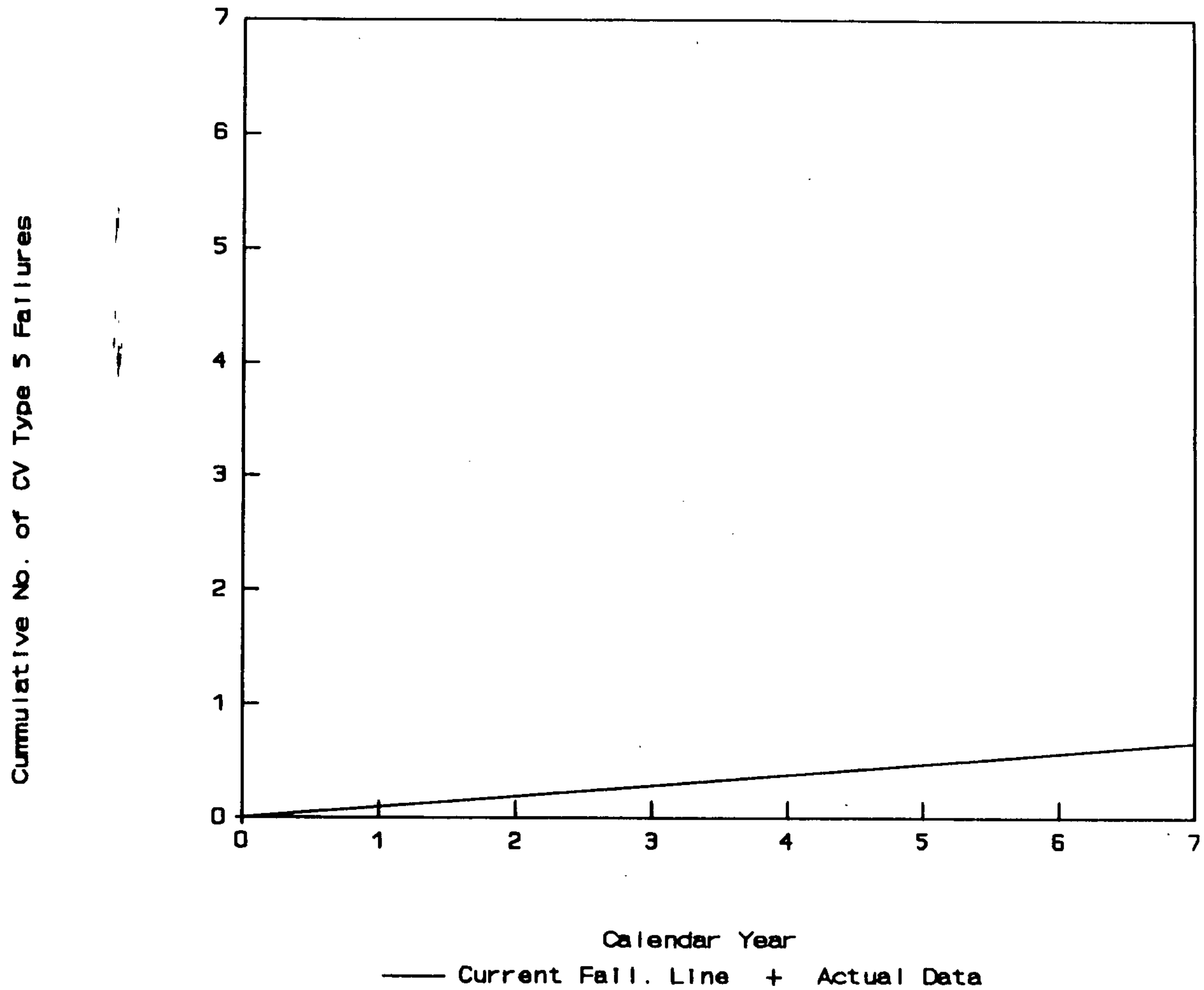
Adjusted SV Type 3 Failure Rate = 2.05E-07/hr
Slope of Current Failure Line = [(adjusted SV Type 2 F.R.) * (operating hours)] / (calendar years)
= [(2.05E-07/hr) * (2.917E-06 hrs)] / (6.42 cal. yrs) = 0.093 fail./cal. yr.

Figure 1C - TRACKING BB-95/96 STOP VALVE (SV) TYPE 3 FAILURES



Adjusted CV Type 4 Failure Rate = 1.22E-06/hr
Slope of Current Failure Line = [(adjusted CV Type 4 F.R.) * (operating hours)] / (calendar years)
= [(1.22E-06/hr) * (3.925E-06 hrs)] / (6.42 cal. yrs) = 0.75 fail./cal. yr.

Figure 1D - TRACKING BB-95/96 CONTROL VALVE (CV) TYPE 4 FAILURES



Adjusted CV Type 5 Failure Rate = 1.53E-07/hr

Slope of Current Failure Line = [(adjusted SV Type 2 F.R.) * (operating hours)] / (calendar years)

= [(1.53E-07/hr) * (3.925E-06 hrs)] / (6.42 cal. yrs) = 0.094 fail./cal. yr.

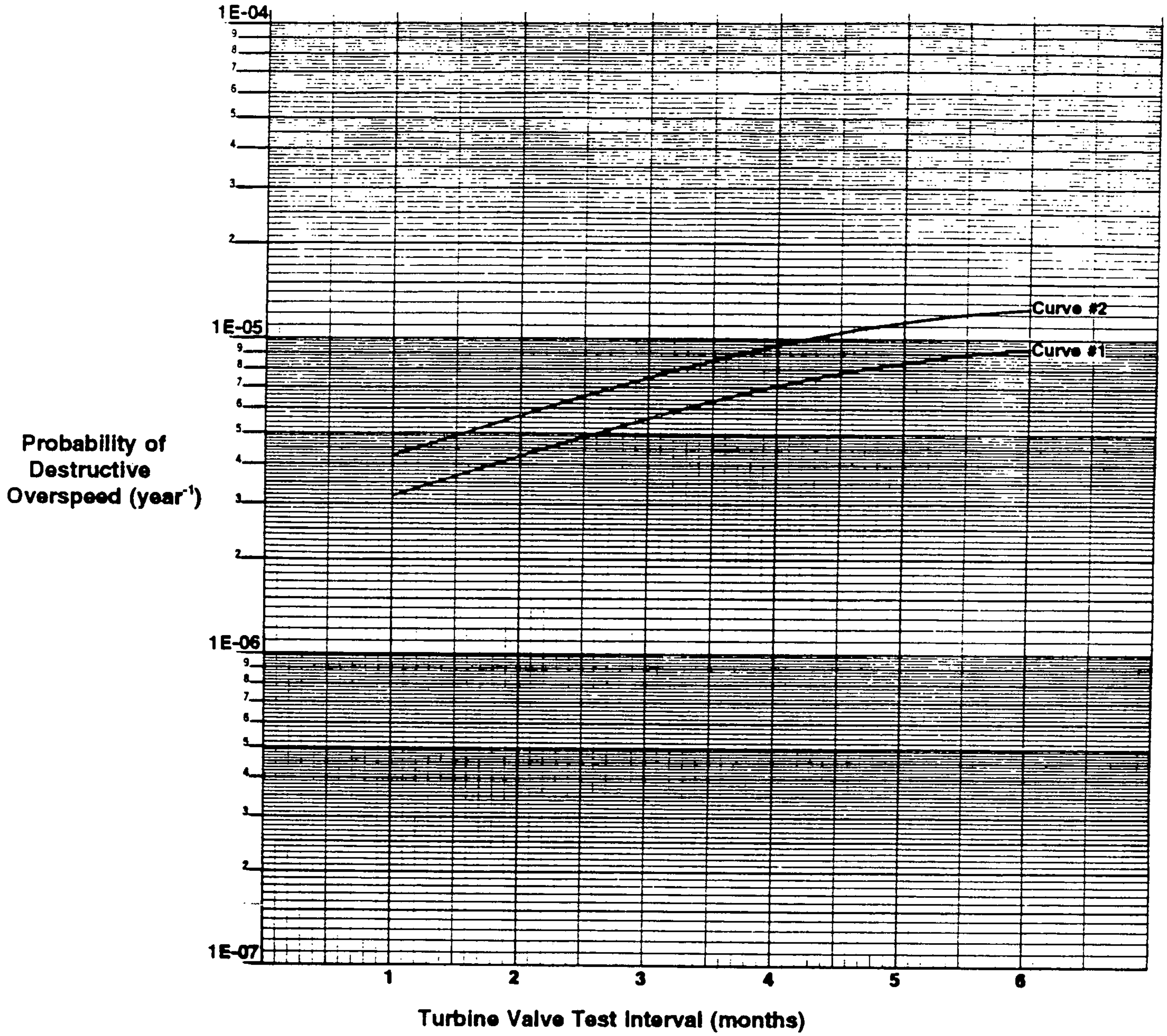
Figure 1E - TRACKING BB-95/96 CONTROL VALVE (CV) TYPE 5 FAILURES

Figure 2

ANNUAL FREQUENCY OF DESTRUCTIVE OVERSPEED FOR VARIOUS BB-95/96 TURBINE VALVE TEST INTERVAL

(1-on-1 SV-CV Turbine / 1 out of 4 Steam Paths)

Initial Case



Curve #1: Surveillance of stop valve discs occurs every 18 months. Testing of valve freedom of movement occurs at intervals of 1 to 6 months (horizontal axis).

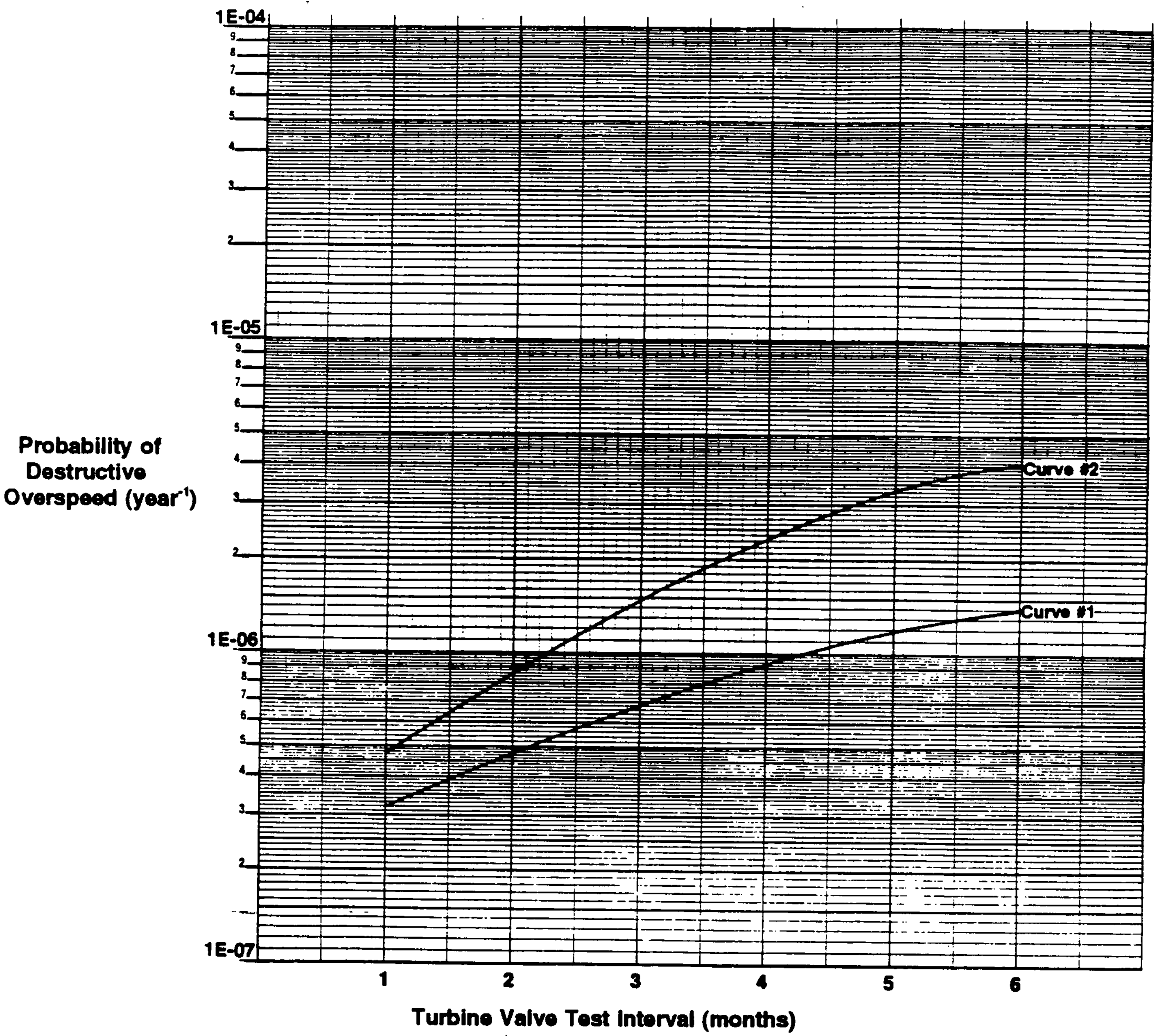
Curve #2: Surveillance of stop valve discs occurs every 24 months. Testing of valve freedom of movement occurs at intervals of 1 to 6 months (horizontal axis).

Figure 3

ANNUAL FREQUENCY OF DESTRUCTIVE OVERSPEED FOR VARIOUS BB-95/96 TURBINE VALVE TEST INTERVAL

(1-on-1 SV-CV Turbine / 1 out of 4 Steam Paths)

Revised Case: 18-mo Refueling Interval



Curve #1: Surveillance of stop valve discs occurs once a day. Testing of valve freedom of movement occurs at intervals of 1 to 6 months (horizontal axis).

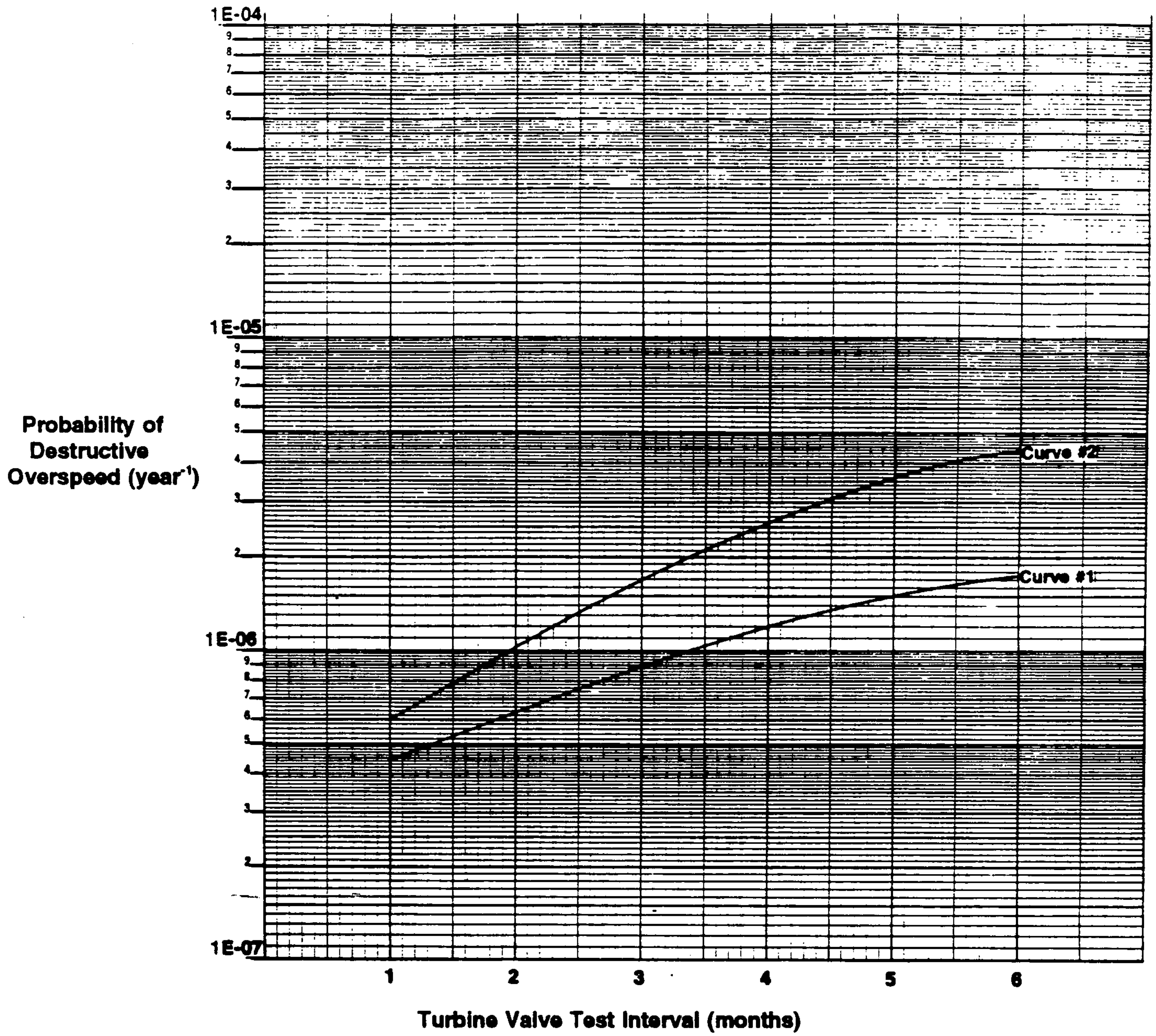
Curve #2: Surveillance of stop valve discs and testing of valve freedom of movement occur concurrently at intervals of 1 to 6 months (horizontal axis).

Figure 4

ANNUAL FREQUENCY OF DESTRUCTIVE OVERSPEED FOR VARIOUS BB-95/96 TURBINE VALVE TEST INTERVAL

(1-on-1 SV-CV Turbine / 1 out of 4 Steam Paths)

Revised Case: 24-mo Refueling Interval



Curve #1: Surveillance of stop valve discs occurs once a day. Testing of valve freedom of movement occurs at intervals of 1 to 6 months (horizontal axis).

Curve #2: Surveillance of stop valve discs and testing of valve freedom of movement occur concurrently at intervals of 1 to 6 months (horizontal axis).