SIEMENS
Westinghouse

TP-04124

MISSILE PROBABILITY ANALYSIS FOR THE SIEMENS 13.9M^2 RETROFIT DESIGN OF LOW-PRESSURE TURBINE BY SIEMENS AG

SUBMITTED TO:
THE NUCLEAR REGULATORY COMMISSION AS TOPICAL REPORT TP-04124-NP-A
FOR PUBLIC RECORD

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ORLANDO, FL

June 7, 2004

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Abstract

Previously in Topical Report TR-03143-NP-A, "Missile Analysis Methodology for GE Nuclear Steam Turbine Rotors by the SWPC", the Siemens missile analysis methodology was accepted by the NRC for referencing in licensing applications or other regulatory applications to the extent specified and under the limitations delineated in the report and in the associated NRC safety evaluation (SE). This acceptance pertained to the missile probability analysis of both GE and Siemens rotors. Implied in the analysis was disc inspection intervals up to 10 operating years (87,600 operating hours).

The submittal addressed in this current Topical Report requests application of this same missile analysis methodology on the Siemens 13.9m2 design and other similar LP retrofit designs for increased disc inspection interval from 87,600 to 100,000 operating hours provided that no cracks are detected.

The Topical Report includes the following documentation:

1. The NRC safety evaluation (SE) and acceptance cover letter dated March 30, 2004.

2. Siemens Westinghouse Power Corporation Technical Report CT-27332-NP, Revision 2, dated August 8, 2003. This report justifies external missile probabilities out to 100,000 operating hours in comparison with the NRC limit.

3. Historical review information, questions and accepted responses that pertain to this issue in the Appendix.

This report is the unrestricted version of TR-04108[1] and is made available for public record.

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[1] Specific portions of this report have been deleted, as indicated by [ ], such as text, tabulated data and figures because they are considered to be of a proprietary nature. SWPC submitted an Affidavit to the NRC dated July 14, 2003 on this basis, which was accepted by the NRC. Criteria identified in the deletions include one or more of the following:

a) The information reveals details of SWPC research and development plans and programs or their results.

b) Use of SWPC information by a competitor would permit the competitor to significantly reduce its expenditures, in time and resources, to design, produce, or market a similar product or service.

c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for SWPC.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 30, 2004

Mr. Stan Dembkowski, Director
Operating Plant Services
Siemens Westinghouse Power Corporation
4400 Alafaya Trail, MC650
Orlando, FL 32826-2399

SUBJECT: FINAL SAFETY EVALUATION REGARDING REFERENCING THE SIEMENS TECHNICAL REPORT NO. CT-27332, REVISION 2, "MISSILE PROBABILITY ANALYSIS FOR THE SIEMENS 13.9 M^2 RETROFIT DESIGN OF LOW-PRESSURE TURBINE BY SIEMENS AG" (TAC NO. MB7964)

Dear Mr. Dembkowski:

By letter dated March 5, 2003, and its supplement dated August 8, 2003, Siemens Westinghouse Power Corporation (SWPC) submitted Technical Report (TR) CT-27332-P, Revision 2, "Missile Probability Analysis for the Siemens 13.9 M^2 Retrofit Design of Low-pressure Turbine by Siemens AG," to the staff for review. On February 10, 2004, an NRC draft safety evaluation (SE) regarding our approval of CT-27332-P, Revision 2 was provided for your review and comments. By letter dated February 26, 2004, SWPC commented on the draft SE. The staff's disposition of your comments on the draft SE are discussed in the attachment to the final SE enclosed with this letter.

The staff has found that CT-27332-P, Revision 2 is acceptable for referencing as an approved methodology in plant licensing applications. The enclosed safety evaluation documents the staff's evaluation of SWPC's justification for the improved methodology.

Our acceptance applies only to the material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that SWPC publish an accepted version within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed SE between the title page and the abstract. It must be well indexed such that information is readily located. Also, it must contain in appendices historical review information, such as questions and accepted responses, draft SE comments, and original report pages that were replaced. The accepted version shall include a "-A" (designating "accepted") following the report identification symbol.

If the NRC's criteria or regulations change so that its conclusions in this letter, that the TR is acceptable, is invalidated, SWPC and/or the licensees referencing the TR will be expected to revise and resubmit its respective documentation, or submit justification for the continued applicability of the TR without revision of the respective documentation.

Sincerely,

/RA/

Herbert N. Berkow, Director
Project Directorate IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 721

Enclosure: Safety Evaluation

cc w/encl:
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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TECHNICAL REPORT NO. CT-27332, REVISION 2

"MISSILE PROBABILITY ANALYSIS FOR THE SIEMENS 13.9 M^2 RETROFIT DESIGN OF

LOW-PRESSURE TURBINE BY SIEMENS AG"

SIEMENS WESTINGHOUSE POWER CORPORATION

PROJECT NO. 721

1.0 INTRODUCTION

By letter dated March 5, 2003, and supplement dated August 8, 2003, Siemens Westinghouse Power Corporation (SWPC) submitted for NRC review and approval its missile probability analysis for the Siemens 13.9 m^2 retrofit design of low-pressure (LP) turbine rotors in Technical Report No. CT-27332, Revision 2. The NRC approved on February 3, 1998, the SWPC missile analysis methodology for General Electric (GE) nuclear LP steam turbine rotors for up to 87,600 operating hours between disc inspections providing that no cracks are detected in the discs. The current technical report justifies the external missile generation probability in extending the disc inspections of the Siemens 13.9 m^2 retrofit design of LP rotors for up to 100,000 operating hours with quarterly test frequency for the main turbine stop and control valves as previously approved. SWPC intends to facilitate the process for applicants that plan to reference this technical report in their future plant-specific applications on turbine missiles by demonstrating that the calculated missile generation probability for the Siemens 13.9 m^2 retrofit design of LP turbine rotors would satisfy the NRC's turbine system reliability criteria. Recently, the NRC approved the latest version of the Siemens turbine missile methodology (the Siemens methodology) in a safety evaluation (SE) dated July 22, 2003, "Safety Evaluation Regarding Referencing the Siemens Westinghouse Topical Report, 'Missile Analysis Methodology for General Electric (GE) Nuclear Steam Turbine Rotors by Siemens Westinghouse Power Corporation (SWPC)'." The positions established in that SE have also been used in evaluating the current submittal.

2.0 REGULATORY EVALUATION

General Design Criterion (GDC) 4 requires that structures, systems, and components (SSCs) important-to-safety be protected against the effects of missiles that might result from equipment failures. The steam turbine is considered to be one of these components because if its massive rotors fail at a high rotating speed during normal operating conditions of a nuclear unit, high energy missiles could be generated that have the potential of damaging safety-related SSCs.

In the past, evaluation of the likelihood of turbine missiles as related to public health and safety followed Regulatory Guide (RG) 1.115, "Protection Against Low-Trajectory Turbine Missiles," and three Standard Review Plan (SRP, NUREG-0800) sections: Section 10.2, "Turbine Generator"; Section 10.2.3, "Turbine Disk Integrity"; and Section 3.5.1.3, "Turbine Missiles." As specified in SRP Section 3.5.1.3, the probability of unacceptable damage from turbine missiles is expressed as the product of the following items: (1) the probability of turbine missile generation resulting in the ejection of turbine disk (or internal structure) fragments through the turbine casing, P_1, (2) the probability of ejected missiles perforating intervening barriers and striking safety-related SSCs, P_2, and (3) the probability of struck SSCs failing to perform their safety functions, P_3. Over the years the NRC staff has shifted its emphasis in the review of turbine missile issues from the strike and damage probability, $P_2 \times P_3$, to the missile generation probability, P_1. The minimum reliability requirement for loading the turbine and bringing the system on line was established in Appendix U of NUREG-1048, Supplement No. 6, "Safety Evaluation Report Related to the Operation of Hope Creek Generating Station," as: $P_1<10^{-4}$ for favorably oriented turbines and $P_1<10^{-5}$ for unfavorably oriented turbines. Currently, the maintenance and inspection of turbine rotors and valves are based on the P_1 calculation, operating experience of similar equipment, and inspection results. These are the criteria that future plant-specific applications using the Siemens methodology will be required to meet.

3.0 TECHNICAL EVALUATION

The prior SWPC submittal dated May 16, 2002, which was evaluated in the July 22, 2003 SE, contains the Siemens methodology and some rotor-specific information regarding GE and Siemens rotors. However, since the emphasis was on the Siemens methodology, not actual application of it, complete information for a certain product line of rotors was not submitted for the NRC's review. The current submittal, however, applies to only Siemens 13.9 m^2 retrofit design of LP turbine rotors. Since complete rotor-specific information was not reviewed in the July 22, 2003, SE and there are multiple plants having these Siemens retrofit design rotors, treating the current submittal as a topical report is warranted.

In the current submittal, the probability of an external missile P_1 is expressed as $P_1 = \sum(P_{2r} \times P_{3r} + P_{1o})$, where P_{2r}, the probability of disk burst up to 120 percent of the rated speed, can be obtained by multiplying the probability of initiation, P_{2ri}, by the probability of crack growth to the critical depth, P_{2rg}; and P_{3r} is the probability of casing penetration given a disk burst up to 120 percent of the rated speed. The derivation and discussion of this equation is contained in the NRC staff's July 22, 2003 SE. That SE also includes the NRC staff's positions regarding acceptable values for some key deterministic and probabilistic parameters used in a typical turbine missile analysis considering disk burst and casing penetration. In its August 8, 2003, response to the NRC's request for additional information (RAI) regarding these input parameters, SWPC states that only two input parameters are not consistent with the NRC staff recommendation: the maximum crack depth for considering crack branching and the friction coefficient for considering turbine casing penetration. This evaluation discusses these two parameters and two other technical areas which were not reviewed in the July 22, 2003, SE.

3.1 Factor Affecting the PDBURST Result P_{2rg} - Crack Branching Effect

PDBURST is a computer program that calculates P_{2rg}, the probability that an assumed crack in a turbine disk will grow to the critical depth. The deterministic part of the PDBURST computer program is based on linear elastic fracture mechanics (LEFM), with the disk burst failure defined as the critical condition when the calculated crack depth equals the critical crack depth. The Siemens methodology includes a crack branching effect and a Siemens stress corrosion cracking (SCC) crack growth rate in the disk burst failure criterion. SCC in turbine disk keyways and bores have been found to yield multiple, irregular-branched cracks. These secondary, branched cracks would share the crack opening displacement at the tip of a main crack, causing a reduction in the stress intensity factor for the main crack. The NRC accepted the use of the 3-inch crack depth for considering crack branching in the July 22, 2003, SE. SWPC, however, used a different value in its current submittal. Instead of justifying the use of this different depth, SWPC revised its turbine missile analysis in its response to the NRC RAI using the value accepted by the NRC, and documented the results in document CT-27332, Revision 2. The NRC staff finds this to be acceptable.

3.2 Factor Affecting the PDMISSILE Result P_{3r} - Friction Coefficient

PDMISSILE is a computer program that calculates P_{3r}, the probability of casing penetration given a disk burst up to 120 percent of the rated speed. The deterministic part of the PDMISSILE computer program is based on an energy balance equation that equates the external missile energy to the difference between the total missile energy at the moment of disk burst at a given rotor speed and the energy dissipation by blade deformation, blade crushing, blade bending, break-off blade vanes, friction between the missile and inner casing, and deformation of the inner casing up to breakage and penetration of the outer casing. In the July 22, 2003, SE, the NRC staff identified the friction coefficient as one of the seven random variables which are major contributors to the calculated probability of casing penetration.

In response to the NRC RAI, SWPC states that using an NRC-accepted value of 0.25 for the friction factor results in increased casing penetration probabilities for each disk. A sensitivity study was also performed by SWPC to evaluate the effects of friction coefficient on casing penetration probability. However, SWPC did not assess the impact of the increased casing penetration probability P_{3r} on the final probability of an external missile P_1 for each disk. The NRC staff performed independent calculations based on the results in Table 5 of CT-27332, Revision 2 and the sensitivity study results, and concluded that the increased casing penetration probability will not change SWPC's conclusion on extending the turbine disk inspection interval from 87,600 to 100,000 operating hours.

3.3 Residual Stresses

The July 22, 2003, SE discusses the Siemens turbine missile methodology without mentioning the residual stresses associated with a particular rotor disk. Since the current submittal discusses the application of the Siemens turbine missile methodology to a certain line of disk design, the disk tangential stresses, which were used in the LEFM analysis of PDBURST, include residual stresses. In regard to the NRC staff's concern over the basis for the proposed residual stress distribution (Figure 8 of the submittal), SWPC provided a Siemens technical paper, "Shrunk on Disk Technology in Large Nuclear Power Plants - the Benchmark against Stress Corrosion Cracking," which contains the basis for the residual stress distribution along with analytical results and experimental verification. The NRC staff reviewed this paper, especially the discussion regarding the use of special heat treatment and rolling to induce compressive stresses at the disk surface. The paper indicates that the induced compressive stresses extend 50 mm into the disk surfaces as shown in Figure 8 of the submittal, and the effect of surface compressive stresses on the turbine SCC prevention is supported by test and operating data. Hence, the NRC staff agrees with SWPC's use of the residual stress distribution in this application.

3.4 Crack Initiation Probability

Similar to the issue discussed in Section 3.3 of this SE, the current submittal considers the crack initiation probabilities for turbine disks in its application of the Siemens turbine missile methodology to a certain line of disk design. However, these probabilities were presented in the submittal without sufficient explanation. Additional information regarding the calculation of these probabilities was provided by SWPC in its response to the NRC's RAI. This information indicates that the calculation is based on 20 years of inspection data for 406 Siemens LP turbine rotor disks using the Poisson distribution. The information also contains calculations for the crack initiation probabilities. This approach, which has been commonly used in risk assessments of nuclear components with low failure rates, is considered acceptable to the NRC staff for this application.

3.5 Total Probability of an External Missile (P_1)

The total probability of an external missile P_1 for the unit at 100,000 hours inspection interval with quarterly valve test frequency of the overspeed protection system is determined to be 3.43E-5 in comparison to the NRC limiting value of 11.42E-5. The same probability for normal operation up to 120 percent rated speed at 100,000 hours of inspection interval is 1.5E-7 in comparison to the NRC limiting value of 1.0E-4 for a favorably oriented unit and 1E-5 for an unfavorably oriented unit. These probabilities are based on the stipulation that no crack is detected in the disk. Therefore, the calculated probabilities, which are lower than the NRC limiting values, are acceptable to the NRC staff.

4.0 <u>CONCLUSIONS</u>

The NRC staff has completed its review of Siemens Westinghouse Power Corporation's Technical Report (CT-27332, Revision 2), and concludes that based on the evaluation discussed above in Section 3.0 on the proposed turbine missile methodology application, it is acceptable to increase the disk inspection interval from 87,600 to 100,000 operating hours with quarterly test frequency for the main turbine stop and control valves provided that no cracks are detected. Because the conclusion is based on detection of no cracks in the turbine disks, all future plant-specific applicants that intend to apply this technical report to their Siemens' 13.9 m^2 retrofit design of LP turbine rotors need to state in their submittals:

a. The approximate date for the turbine disk inspection at the end of 100,000 hours of operation of their rotors,

b. A commitment to inform the NRC about their turbine disk inspection results and plans to reduce the probability of turbine missile generation, P_1, for continued operation should cracks be detected in the inspection, and

c. Justification for any additional turbine missile analyses, or minor deviations that may be plant specific.

This Technical Report can be applied not only to the $13.9m^2$ design, but generically to other designs that are dimensionally different but follow the same missile analysis methodology.

Attachment: Resolution of Comments

Principle Contributor: C. Sheng

Date: March 30, 2004

RESOLUTION OF COMMENTS

ON DRAFT SAFETY EVALUATION FOR SIEMENS WESTINGHOUSE POWER CORPORATION'S TECHNICAL REPORT NO. CT-27332, REVISION 2, "MISSILE PROBABILITY ANALYSIS FOR THE SIEMENS 13.9 M^2 RETROFIT DESIGN OF LOW-PRESSURE TURBINE BY SIEMENS AG"

By letter dated February 26, 2004, Siemens Westinghouse Power Corporation provided a comment on the draft safety evaluation (SE) for Technical Report No. CT-27332, Revision 2, "Missile Probability Analysis for the Siemens 13.9 M^2 Retrofit Design of Low-pressure Turbine by Siemens AG". The following is the staff's resolution of the comment.

1. Siemens Comment: There is one clarity concern. The current submittal and SE applies to Siemens 13.9m^2 retrofit design of LP turbine rotors for 100,000 operating hour disk inspection intervals with quarterly valve test frequency for the main turbine stop and control valves provided that no cracks are detected.

   Our question is: Does the SE only apply to the 13.9m^2 design or can it apply generically to other designs that are dimensionally different but follow the same "advanced disk design" concept, the same missile analysis methodology and give comparable P1 probabilities that are below NRC limits for 100,000 operating hour disk inspection intervals?

   NRC Action: The comment was adopted into the conclusion of the final SE allowing the methodology to be applied to other designs.

SIEMENS TECHNICAL REPORT NO. CT-27332-NP, REVISION 2

Siemens Technical Report

CT-27332-NP Revision 2

Subject/Title
Missile Probability Analysis

Place	Date
Orlando, FL	8/8/2003

Author(s)	Department	Tel.	Signature
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Project
BB81/281 13.9 m^2

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Summary*)

Pages of Text: 27 Appendices:

Missile probability analysis is presented for the Siemens 13.9m^2 retrofit design of LP turbines. These modern upgraded designs are used in various applications including replacement of Westinghouse original BB81 and BB281 nuclear LP rotors and internals.

Results of the analysis indicate that the missile probabilities remain well below the Nuclear Regulatory Commission (NRC) limits of 1E-4 for a favorably oriented unit and 1E-5 for an unfavorably oriented unit for up to 100,000 operating hours between disc inspections providing that no cracks are detected in the discs. Previously, in the submittal for the Limerick Unit [16, 17], the NRC had approved the missile analysis methodology for 10 years, which is about 87,600 operating hours. This report justifies external missile probabilities out to 100,000 operating hours in comparison with the NRC limit. Furthermore, test frequency for the main turbine stop and control valves continues at once every 3 months (quarterly), as previously approved.

*) In Technical Reports add key words (max. 12) at the end of the Summary and enter Export Classification

Distribution (add "f.i.o.", if only Summary is distributed for information):

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James McCracken	S326
Jim Auman	S326
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Index	Vers.	Date	Page(s)	Initials of Author(s)	Initials for Release

Revisions

No.	Date	Description
0	February 26, 2003	Original issue.
1	June 6, 2003	Editorial change to add units to Figures 6 & 7.
2	August 8, 2003	Changes were made to be in full compliance with the NRC Acceptance Letter[18] and Safety Evaluation Report[19].

Contents

1 INTRODUCTION

2 ANALYSIS METHODOLOGY

The most significant source of turbine missile is a burst-type failure of one or more bladed shrunk-on disks of the low-pressure (LP) rotors. Failures of the high-pressure (HP) and generator rotors would be contained by relatively massive and strong casings, even if failure occurred at maximum conceivable overspeed of the unit. There is a remote possibility that some minor missiles could result from the failure of couplings or portions of rotors which extend outside the casings. These missiles would be much less hazardous than the LP disk missiles, due to low mass and energy and therefore, will not be considered.

The probability of an external missile (P_1) is evaluated by conservatively considering two distinct types of LP shrunk-on disk failures, namely:

1) failure at normal operating speed up to 120% of the rated speed P_r and

2) failure due to run-away overspeed greater than 120% of rated speed P_o

for all LP disks as follows:

$$P_1 = P_r + P_o = \sum_{i=1}^{N} P_{1r} \cdot P_{2r}^{i} \cdot P_{3r}^{i} + \sum_{i=1}^{N} P_{1o} \cdot P_{2o}^{i} \cdot P_{3o}^{i}$$

where:

P_1 probability of an external missile

P_r probability of an external missile for speeds up to 120% of rated speed

P_o probability of an external missile for speeds greater that 120% of rated speed

N, i total and current number of the disks

P_{1r} probability of turbine running up to 120% of rated speed (Conservatively assumed = 1.0)

P_{2r}^{i} probability of disk # i burst up to 120% of rated speed due to stress corrosion crack growth to critical size

P_{3r}^{i} probability of casing penetration given a burst of the disk # i up to 120% of rated speed

P_{1o} probability of a run-away overspeed incident (>120% of rated speed) due to failure of overspeed protection system

P_{2o}^{i} probability of disk burst given run-away overspeed incident (Conservatively assumed = 1.0)

P_{3o}^{i} probability of casing penetration given a burst of the disk # i at run-away overspeed (Conservatively assumed = 1.0)

The overspeed probability P_{1o} is a function of the maintenance and test frequency of the speed control and overspeed protection system.

The probability of normal operating speeds up to 120% of the rated speed is assumed to be 1.0. It is also conservatively assumed that, given the overspeed protection system fails the probability of a disk # i burst and that of casing penetration of the burst fragments are also 1.0 each for all disks.

Finally, the expression for the external missile probability could be re-written as:

$$P_1 = P_r + P_o = \sum_{i=1}^{N} P_{2r}^{i} \cdot P_{3r}^{i} + P_{1o}$$

Therefore, the only remaining values that need to be quantified are P_{2r}^{i}, P_{3r}^{i} and P_{1o}.

The methodology for evaluation these probabilities is described in the following sections.

2.1 NRC Criteria for Missile Probability

The US Nuclear Regulatory Commission (NRC) has defined criteria governing nuclear steam turbine start-up, continued operation and shut down requirements.

Two power plant layouts, namely unfavorable and favorable orientations, have been identified as shown in Fig. 1.

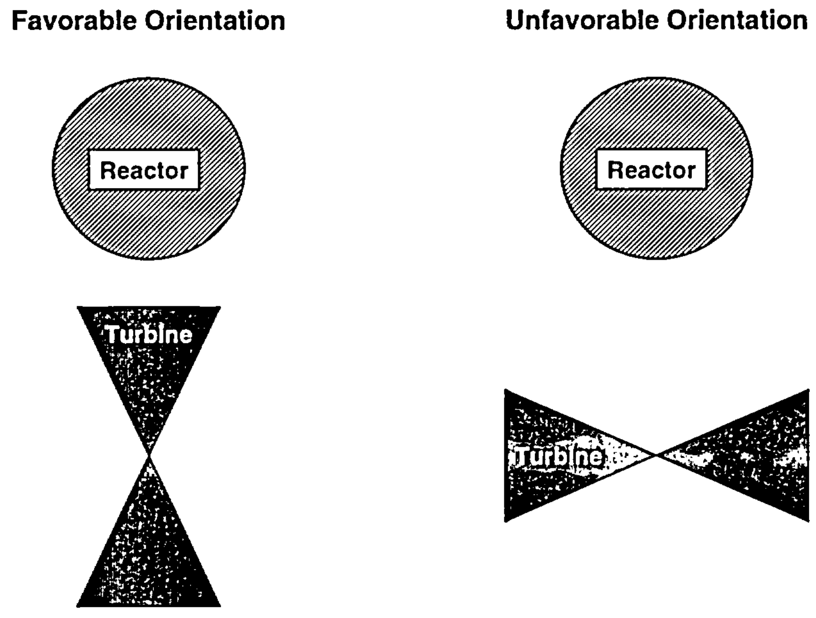


Fig. 1 Nuclear turbine unit orientation relative to reactor building

Table 1 shows the allowable limits for the probability of external missile from the steam turbine – generator unit (P_1) for start-up and continued operation. The overspeed protection system test with maintenance frequencies and disk inspection intervals must be selected to ensure that these criteria are satisfied.

Favorably Oriented Turbine	Unfavorably Oriented Turbine	Required Licensee Action
(A) $P_1 < 10^{-4}$	$P_1 < 10^{-5}$	This is general, minimum reliability requirement for loading the turbine and bringing the system on line
(B) $10^{-4} < P_1 < 10^{-3}$	$10^{-5} < P_1 < 10^{-4}$	If this condition is reached during operation, the turbine may be kept in service until the next scheduled outage, at which time the licensee is to take action to reduce P_1 to meet the appropriate A criterion before returning the turbine to service
(C) $10^{-3} < P_1 < 10^{-2}$	$10^{-4} < P_1 < 10^{-3}$	If this condition is reached during operation, the turbine is to be isolated from the steam supply within 60 days, at which time the licensee is to take action to reduce P_1 to meet the appropriate A criterion before returning the turbine to service
(D) $10^{-2} < P_1$	$10^{-3} < P_1$	If this condition is reached during operation, the turbine is to be isolated from the steam supply within 6 days, at which time the licensee is to take action to reduce P_1 to meet the appropriate A criterion before returning the turbine to service

Table 1 Turbine System reliability Criteria (NRC GUIDE NUREG-1048 Table U1)

3 INTEGRITY ANALYSIS

3.1 Stress Corrosion Cracking (SCC)

When materials such as used in turbine disks (Fig. 2) are exposed to sustained high tensile stress and an aggressive moist environment, cracks initiate and grow with time.

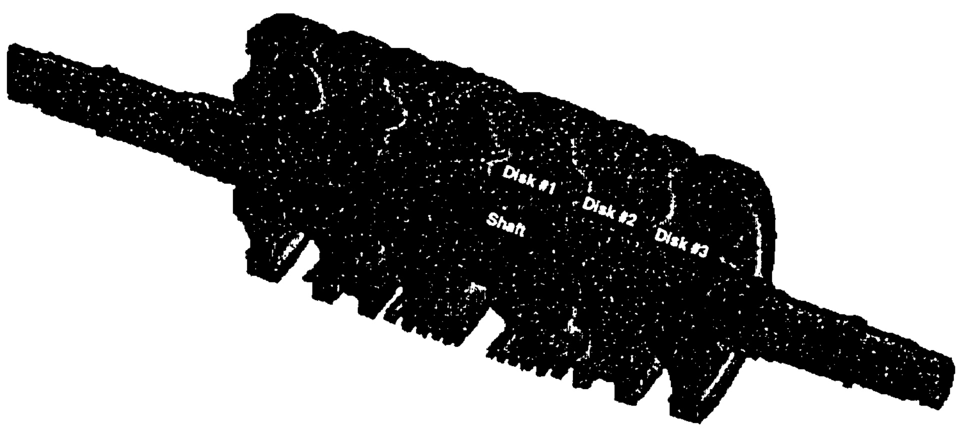


Fig. 2 Rotor with shrunk-on disks

This phenomenon is known as Stress Corrosion Cracking (SCC). Low pressure steam turbine shrunk-on disks with high stresses at the bore are susceptible to stress corrosion cracking. As a crack initiates and then grows with operating time, the stress intensity factor associated with the crack also increases. Finally, when the stress intensity factor approaches and equals the critical stress intensity factor for the material which is the fracture toughness property, a disk burst condition occurs. Alternatively, a critical crack corresponding to the material fracture toughness is calculated, and a burst condition is considered to occur when the crack size approaches and equals the critical crack size.

Siemens has conducted extensive studies into the SCC behavior of materials used for rotor disks. The results of the investigations can be summarized as follows.

SCC consists of an initial crack initiation period in which pitting or cracks are formed which is followed by a crack growth period.

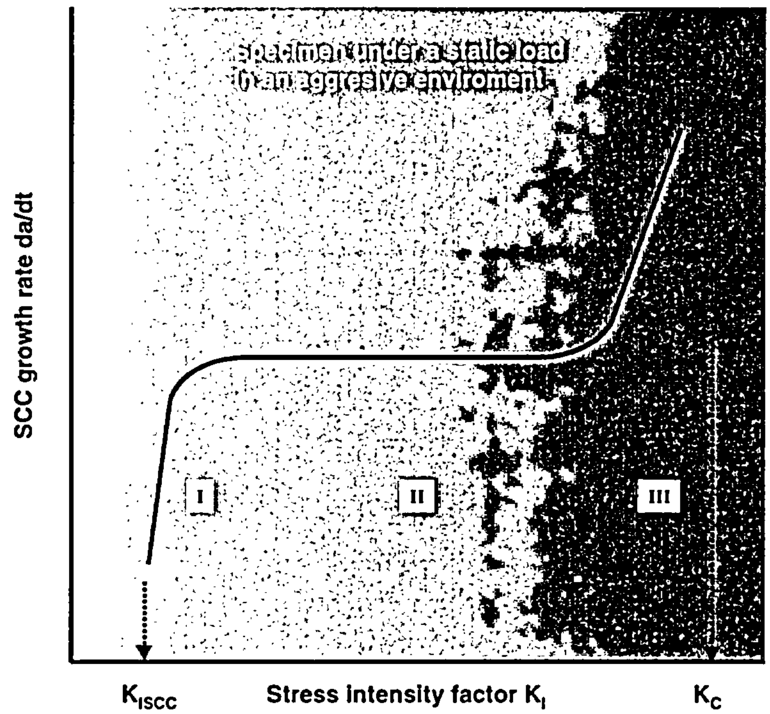


Fig. 3 Schematic dependency SCC growth rate versus stress intensity factor

Fig. 3 shows schematically the SCC growth rate as a function of the applied stress intensity factor K_I, which exhibits three distinct regions. Region I shows that no crack growth occurs below a threshold value of K_{ISCC} (typically of the order of about 20-30 MPa·√m). During region II SCC growth rate is virtually independent of the stress intensity level, until K_I approaches the material fracture toughness level. Then in region III SCC growth rate increases rapidly leading to fracture.

Impurities in steam, conditions promoting flow stagnation such as crevices, steam condensation, ratio of stress to yield strength and level of yield strength significantly influence the potential for SCC.

In high purity water with a conductivity of < 0.2µS/cm, SCC initiation is influenced only by the quenching and tempering process which establishes the material's yield strength value. If the yield strength exceeds approximately 1085 MPa (157 ksi), the material becomes susceptible to SCC due to hydrogen embrittlement. Up to this threshold, no stress corrosion crack initiation occurred even when operating stress exceeded the yield strength in notched specimens. This result is also not affected by the purity of steel. Under high purity water conditions, even nonmetallic inclusions (e.g. Al_2O_3, MnS etc.) do not act as crack starters at the material surface. Such inclusions do not influence the resistance to stress corrosion cracking. This even applies to water with low oxygen content as well as to oxygen saturated water. Pit formation was also not found under these corrosive conditions.

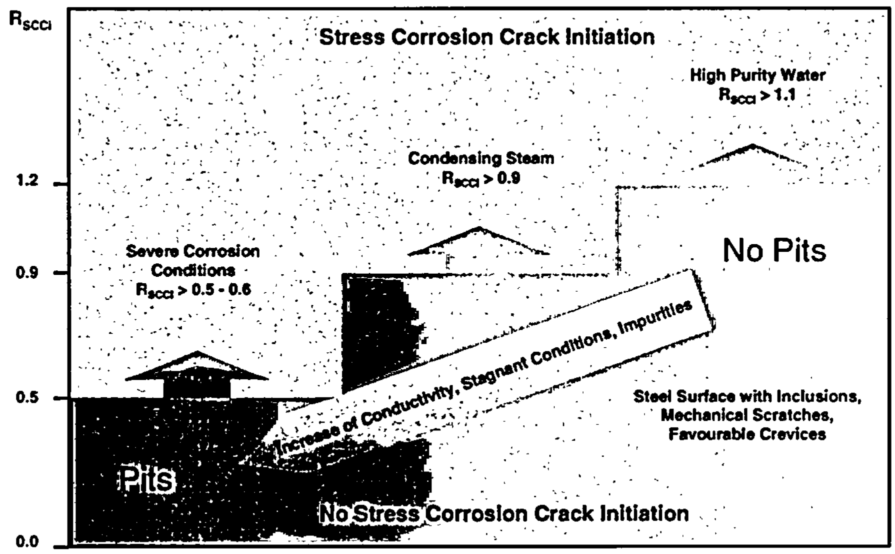


Fig. 4 Stress corrosion crack initiation of LP turbine rotor steels with 0.2% offset yield strengths < 1000 MPa (145 ksi)

Findings from extensive testing, power plant experience and review of literature leads to Fig. 4. For yield strengths less than 1000 MPa, this figure shows at what operating stress to yield strength ratios, stress corrosion crack initiation can be expected for specific environment conditions. As shown in the figure, an improvement of the operating environment permits high stress levels up to and above the yield strength level of the material. The diagram also reveals that with stress levels below 60% of the yield strength, stress corrosion cracking has not occurred even under severe corrosion conditions.

3.2 Failure Assessment Procedure

Because of the large disk bore diameter, defects on the bore surface can be treated using the basic fracture mechanics model for the case of a semi-elliptical surface crack in an infinite plate subjected to tension loading σ_{eff}. This leads to the expression for the critical crack size a_{crit} at which a disk would rupture due to brittle fracture (within the “small scale yielding” approach) given by:

$$a_{crit} = \frac{Q}{1.21 \cdot \pi} \cdot \left(\frac{K_{Ic}}{\sigma_{eff}} \right)^2 ,$$

where:

K_{Ic} = Fracture toughness,

σ_{eff} = Effective tangential bore stress due to the combined action of centrifugal loads and residual compressive stresses (manufacturing) corresponding to the Fig.5.

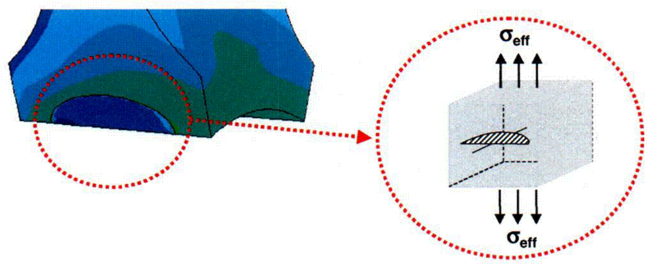


Fig. 5 Fracture mechanics model

The crack shape parameter Q is a combination of the square of the complete elliptical integral of the second kind and "small scale yielding" correction:

$$Q = E(k)^2 - 0.212\left(\frac{\sigma}{\sigma_Y}\right)^2$$

It can be for computational reasons approximated by the expression:

$$Q = 1 + 1.464 \cdot \left(\frac{a}{c}\right)^{1.65} - 0.212 \cdot \left(\frac{\sigma}{\sigma_Y}\right)^2$$

3.3 Stress Analysis

The finite element analysis of the rotor with the shrunk-on disks (Fig. 2) was conducted to determine the temperature and stress distribution due to the combined effect of shrink fit, thermal and centrifugal mechanical loads. The disk material is 26NiCrMoV14-5.

Temperature (Fig. 6) and tangential stress (Fig. 7) distributions in the disks are computed using a commercial Finite Element Code ABAQUS [9]. All appropriate loading conditions must be considered in order to obtain the appropriate stress distributions for input to the fracture mechanics evaluation in the location of interest.

C01

[

] b,c

Fig. 6 Temperature distribution
(Units in Degrees C)

[

] b,c

Fig. 7 Tangential stress distribution
(Units in MPa)

Fig. 8 shows schematically the blue-colored compressive stress region (the width about 50 mm) and red-colored tensile stress region in the disk after special heat treatment during manufacturing. The corresponding distribution of the residual stress is presented as a brown line. The tangential stress distribution at 20% overspeed near the disk bore at the maximal stress location is shown as a red line. The combined effective stress distribution is presented as a dashed blue line.

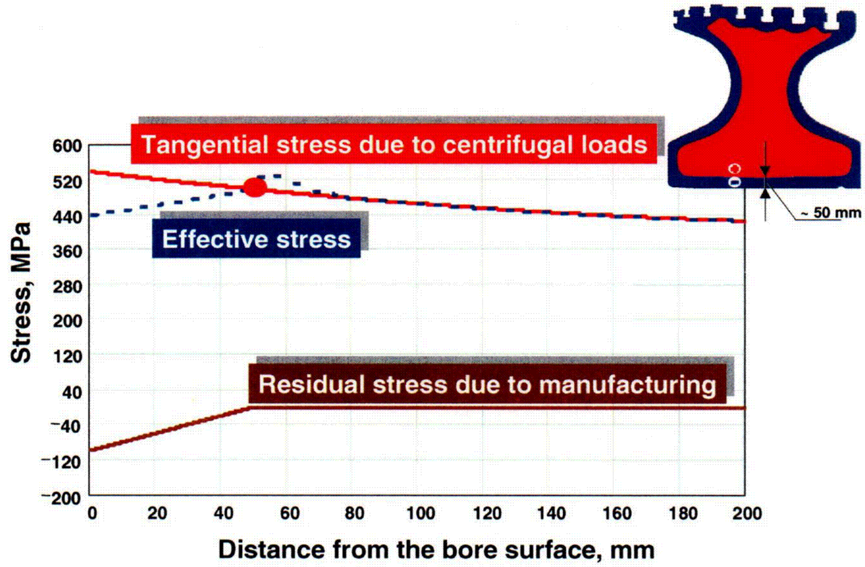


Fig. 8 Tangential (at 120% of rated speed), residual and effective stress distribution in the disk #1

3.4 Probabilistic Fracture Mechanics Analysis

For probabilistic computations, Siemens has developed a numerical Monte-Carlo simulation code. As a failure condition the brittle fracture mode is assumed:

$$a_{cr}(K_{Ic}, \sigma_Y, \sigma, \xi, k) \leq a_i + \int_0^t \dot{a}(\sigma_Y, T)\,dt\,.$$

Where:

a_{cr} = Critical crack size,

a = Current crack size,

a_i = Initial crack size,

t = Operating time duration,

ξ = Crack shape factor (crack depth to crack length ratio),

K_{Ic} = Fracture toughness,

C02

k = Branching factor,

σ = Applied load due to tangential stress at bore,

σ_Y = Yield strength, and

T = Temperature.

For probabilistic analysis the critical crack size is defined as that given by the equation in Section 3.2 or 100 mm whichever is smaller. The 100-mm limit is purely based on the applicability limitation of linear-elastic fracture mechanics concept and does not necessarily represent an imminent burst condition.

A brief description of selected random variables is given below.

3.4.1 Load

It is assumed that FE Analysis provides accurate results within 5% of tolerance due to the uncertainties in geometry as well as thermal and mechanical loads. A normal distribution is assumed. The mean values are shown in Table 2.

	Disk # 1	**Disk # 2**	**Disk # 3**
Metal temperature [°C]	[ ] b,c	[ ] b,c	[ ] b,c
Tangential stress [MPa]	[ ] b,c	[ ] b,c	[ ] b,c

Table 2 FE computation results

3.4.2 Crack Branching Factor

The branching factor k is assumed to be normally distributed with a mean of 0.65 and a standard deviation of 0.175, whereby

$$k = \begin{cases} 0.65 \; if \;\; Crack\,Depth \le 3\,in \\ 1 \quad otherwise \end{cases}$$

3.4.3 Fracture Toughness

The normal distribution has been used in describing scatter in fracture toughness data with a mean of [ ] b,c $MPa \cdot \sqrt{m}$ and standard deviation of [ ] b,c % of the mean value.

3.4.4 Yield Strength

The yield strength values are assumed to be distributed normally with mean and standard deviation values based on internal investigation data:

Disk # 1: $\sigma_Y = [\ ]^{b,c} MPa\ and\ std.deviation = [\ ]^{b,c}\ MPa$

Disk # 2 and 3: $\sigma_Y = [\ ]^{b,c}\ MPa\ and\ std.deviation = [\ ]^{b,c}\ MPa$

3.4.5 SCC Growth Rate

As shown in Fig. 3 the stress corrosion cracking (SCC) rate is assumed to be independent on the stress intensity level. The main parameters influencing the SCC rate are temperature, material yield strength and water chemistry. Based on field measurements and laboratory test data the empirical equations for SCC rates were developed. For the probabilistic analysis the Westinghouse SCC rate is used:

$$\frac{da}{dt} = \exp(-4.968 - \frac{7302}{T+460} + 0.0278 \cdot \sigma_Y),$$

Where the SCC rate is given in inches/hour, temperature T in °F and the material yield strength σ_Y in ksi.

The log-normal distribution of Westinghouse-SCC rate with a standard deviation of 0.578 is assumed.

3.4.6 Initial Crack Size

The initial crack size is assumed to be a non-varying variable with the value a_i = 3 mm.

3.4.7 SCC Initiation Model

Since SCC initiation is not understood well enough to be quantifiable as a function of time, it is modeled based on the observed cracking experience of the turbine disks in the field.

3.4.7.1 „Old" Approach

To date a total of 82 Siemens AG PG #1 disks and 324 latter disks from 41 ten and eight disk LP rotors in operation have been inspected or re-inspected world wide over the last 20 years. Two of the newest six disk design rotors have been in operation only since September 1996 and eight more installed during 1997-99. Thus, no inspections have been made on these six disks design rotors to date. Only one #1 disk on a ten disks design rotor was found to have SCC type ultrasonic indication in the disk hub surface. There were no cracks in the higher stressed keyways. This finding was after 67,600 operating hours. This design did not have the benefit of design induced compressive residual stresses on the disk hub bore. Subsequent inspections found crack growth rate to be 3-4 mm per year. An investigation of the cause showed that the disk hub surface was contaminated by microscopic Ni-rich and S-rich particles, which were inadvertently introduced and pressed into the surface during the time of manufacture. This probably acted as the crack starter. Manufacturing procedures were redefined to preclude such occurrences in the future. Small indications were also found on two of the 324 latter disks. The nature of these indications could not be ascertained but are likely to be due to water erosion or SCC. Details of these findings have been reported earlier [11]. These two findings were on the inlet side of the TE and GE disk #4 of the same rotor. This rotor was also of ten disks design unit without induced residual stresses of the disk hub bore. The indications were found after 53,000 operating hours. Evaluation found no limitation to designed operating life, the rotor was returned to service and additional investigation to this time has not been possible due to the disks being in service.

Conservatively, assuming that all of the above indications are due to SCC and using standard statistical evaluation procedures, the crack initiation probabilities at 90% confidence level for the #1 disks are as shown in Table 2.

Disk	Crack Initiation Probability
1	[ ] b,c
2	[ ] b,c
3	[ ] b,c

Table 3 Crack Initiation Probability

3.4.7.2 Modern Approach

The probability of crack initiation in a given disk is estimated from the inspection data of turbine disks and the probability value depends on the disk # and the location of indication, i.e. either the keyway or hub bore. Thus, the crack initiation probability is treated as a binomial variant and estimated directly from field data showing the number of cracks found and the number of disks inspected for each disk type [10]. The probability of crack initiation in a disk # i :

$$q_i = \begin{cases} \dfrac{\text{number of } \#\text{i disks with cracks}}{\text{number of inspected } \#\text{i disks}} \\ 1-(0.5)^{1/(\text{number of inspected } \#\text{i disks})}, \text{ if the number of } \#\text{i disks with cracks} = 0 \end{cases}$$

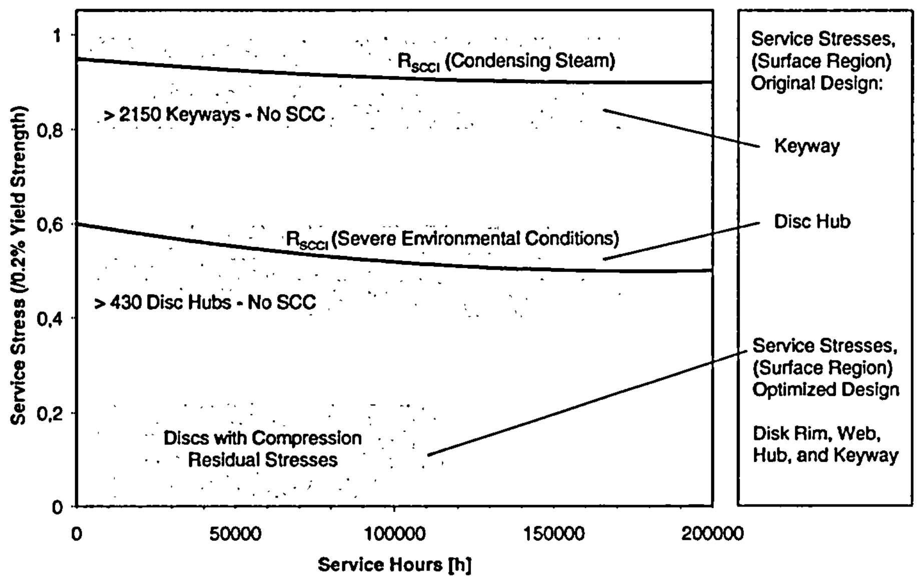


Fig. 9 Results of the investigation on crack initiation

Based on the investigation results [14,15] shown in Fig. 9 the following crack initiation probabilities q_i can be calculated:

Keyway area: $q_i = [\ \ ]^{b,c}$ (2150 investigated keyways without any indication)

Disk hub area: $q_i = [\ \ ]^{b,c}$ (more than 430 investigated disks without any indication)

For the probabilistic calculations the more conservative "old" approach is assumed.

4 PROBABILITY OF CASING PENETRATION FOR SPEEDS UP TO 120% OF RATED SPEED

4.1 Criterion for Casing Penetration Given a Disk Burst

The criterion for an internal missile fragment penetrating the surrounding blade ring and inner and outer casing structure is stated as follows:

$$E_i \geq E_d,$$

where

E_i is the total initial energy of the internal missile due to burst;

E_d is the total energy dissipated due to various resisting factors

A generic description of the procedure is as follows:

4.1.1 Initial Energy

The size of the angular segment of the disk with the blades is determined by maximizing the translational energy of the internal missile. The total energy of the missile segment is given by

$$E_i = \frac{1}{2} \cdot I \cdot \omega_b^{\ 2}$$

Where:

I = Polar moment of inertia of the missile segment;

ω_b = Rotational speed at burst.

4.1.2 Energy Dissipation

Energy dissipation factors considered include blade crushing, blade bending, loss of blade mass due to break off, friction between missile fragment and inner casing structure, deformation of the stationary blade ring and inner casing up to breakage and penetration through the outer casing structure.

4.1.3 Calculation Results

The surrounding casing is designed to prevent external missiles up to at least 120% of rated speed.

The calculated speeds at which ductile burst of disks occurs are [ ] b,c %, [ ] b,c % and [ ] b,c % respectively for the disks # 1, # 2 and # 3.

Based on the Monte Carlo simulation technique with 10^6 calculations the probability of casing penetration at 120% rated speed was determined. The probabilities respectively are [ ] b,c , [ ] b,c and [ ] b,c assuming a friction coefficient of 0.25.

5 OVERSPEED EVENT

Run-away overspeed events (>120% of rated speed) are due to failure of the overspeed protection system which consists of speed monitoring devices, trip and fast closure of steam stop and control valves. Siemens evaluates nuclear and fossil unit control systems together due to common control components, with the older fossil units adding conservatism [2,3]. Based on the upper confidence limit evaluations, the following overspeed probability values are used for the three typical valve test frequencies.

Valve Test Frequency	Probability of Overspeed, Yr^{-1}
Weekly	$1.6 \cdot 10^{-7}$
Monthly	$9.0 \cdot 10^{-7}$
Quarterly	$3.0 \cdot 10^{-6}$

Table 4 Overspeed probability values

For these probabilistic calculations, the probability corresponding to quarterly valve test intervals is conservatively assumed.

6 PROBABILISTIC SIMULATION RESULTS

The probabilistic results were generated using a Monte Carlo simulation technique involving successive deterministic fracture mechanics calculations using randomly selected values of variables described in the Section 4.3. One million simulations were performed for each disk. Reproducibility and consistency of results was tested using various random number generators and random number seeds.

The results of calculations are representatively shown in Table 5.

	Disk #1	Disk #2	Disk #3
P_{2ri}	[ ] b,c	[ ] b,c	[ ] b,c
P_{2rg}	[ ] b,c	[ ] b,c	[ ] b,c
$P_{2r} = P_{2ri} \cdot P_{2g}$	[ ] b,c	[ ] b,c	[ ] b,c
P_{3r}	[ ] b,c	[ ] b,c	[ ] b,c
$P_r = P_{2r} \cdot P_{3r}$	[ ] b,c	[ ] b,c	[ ] b,c
$\sum_{i=1}^{6} P_r$	[ ] b,c	[ ] b,c	[ ] b,c

Table 5 Representative calculation for the 100,000 hours inspection interval

Since $P_{1o} = 3.42 \cdot 10^{-5}$, which is $3.0 \cdot 10^{-6}$ per year for 100,000 hours, the total probability of an external missile (P_1) for the unit at 100,000 hours inspection interval is:

$$P_1 = 1.3 \cdot 10^{-7} + 3.42 \cdot 10^{-5} = 3.43 \cdot 10^{-5} < 11.42 \cdot 10^{-5}$$ (NRC limit value for 100,000 hours)

Results are graphically illustrated in Figures 10 to 12 for Quarterly/Quarterly/Quarterly valve test frequency of the overspeed protection system. Figure 10 compares the external missile probability including overspeed with the NRC limit of 1E-5 per year for an unfavorably oriented unit as a function of the inspection interval in hours. Figure 11 compares the external missile probabilities for normal operation up to and including 120% speed with the NRC limit. Figure 12 compares the internal burst probability at normal operation up to and including 120% speed with inspection interval.

The above plots illustrate that as long as no cracking is detected, the unit can be safely operated for 100,000 hours between inspections.

FIGURE 10

13.9m^2 DESIGN

COMPARISON OF EXTERNAL MISSILE PROBABILITIES INCLUDING OVERSPEED WITH NRC LIMIT

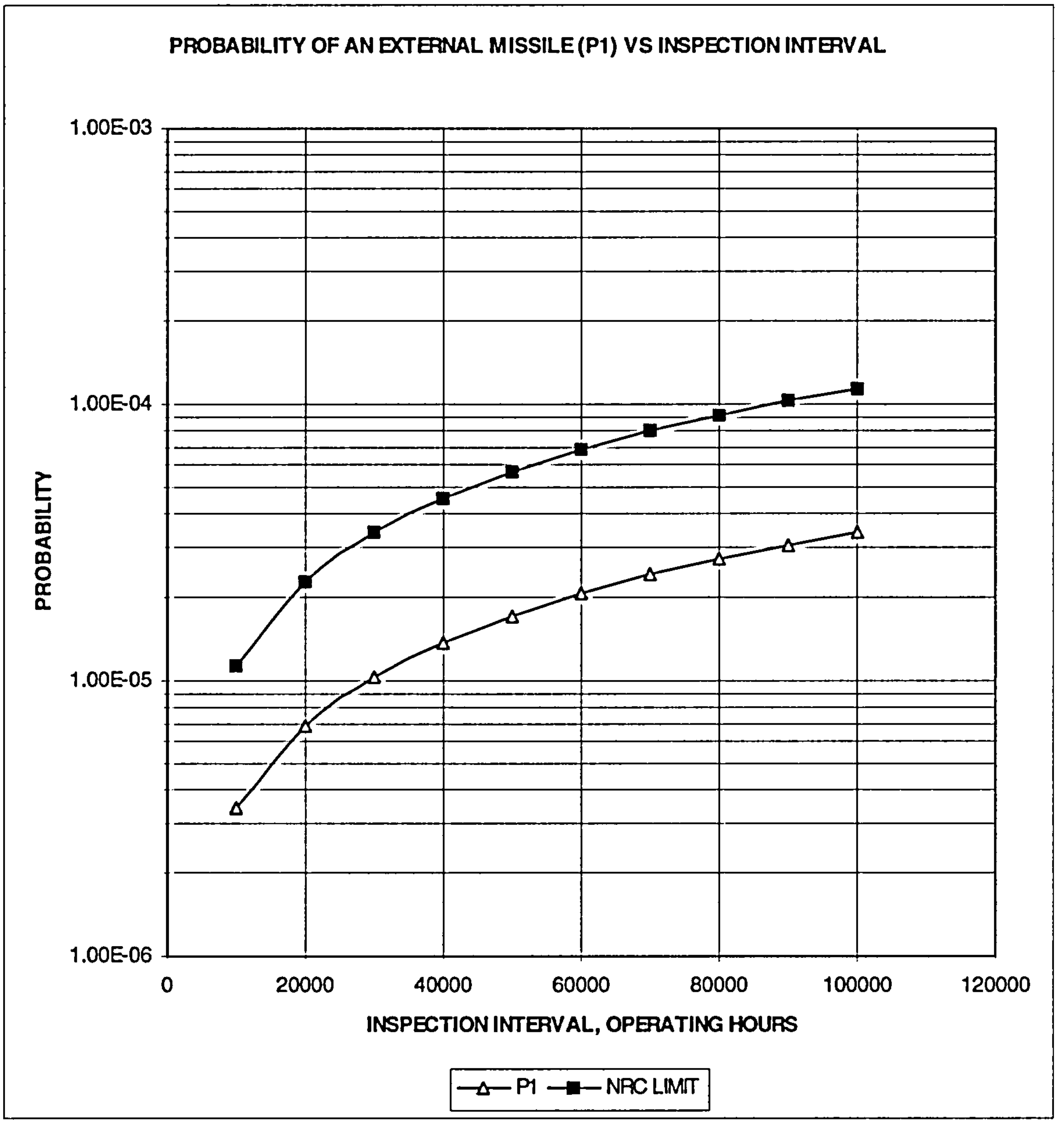


FIGURE 11

13.9 m^2 DESIGN

COMPARISON OF EXTERNAL MISSILE PROBABILITIES FOR NORMAL OPERATION UP TO 120% SPEED WITH NRC LIMIT

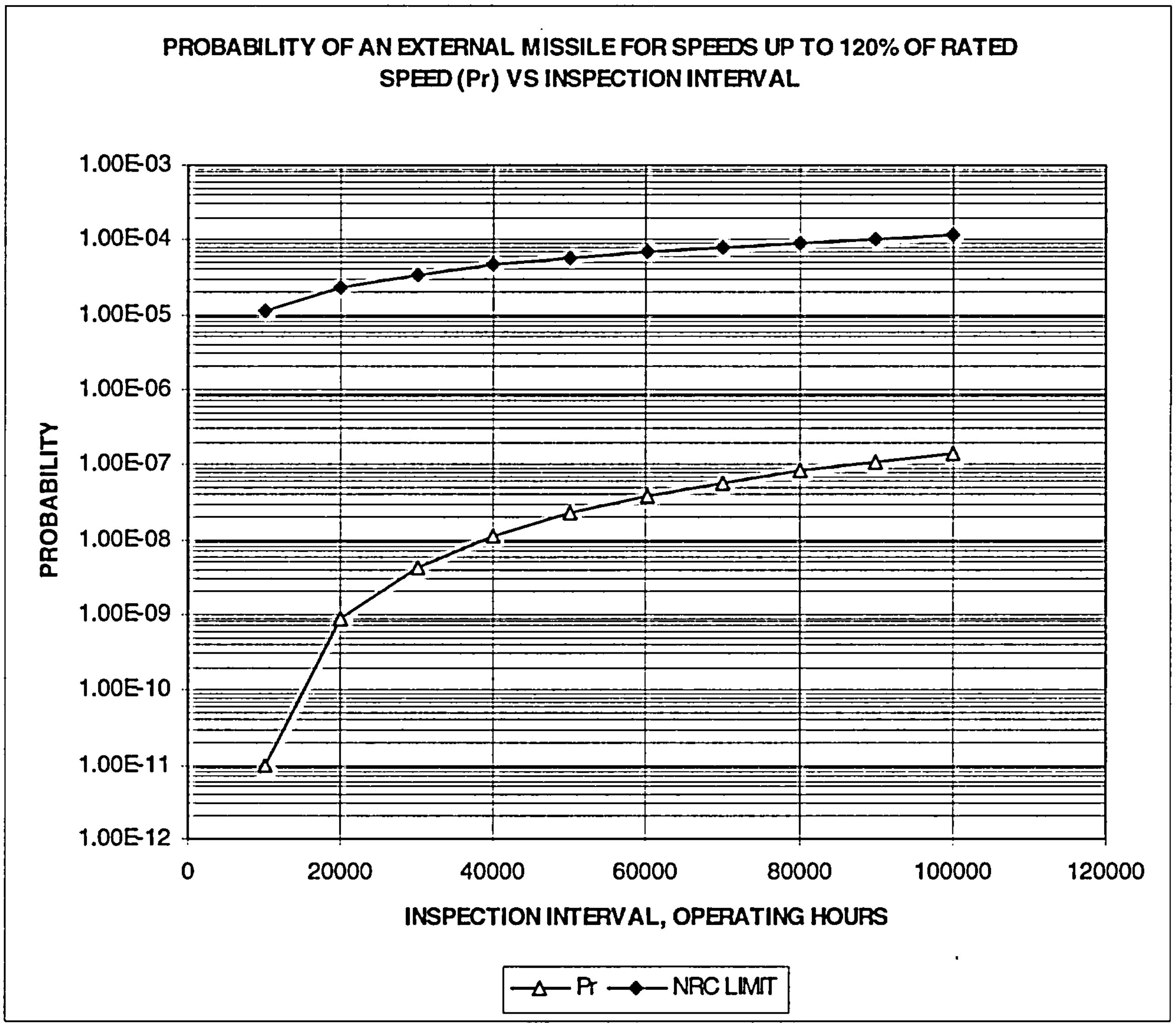
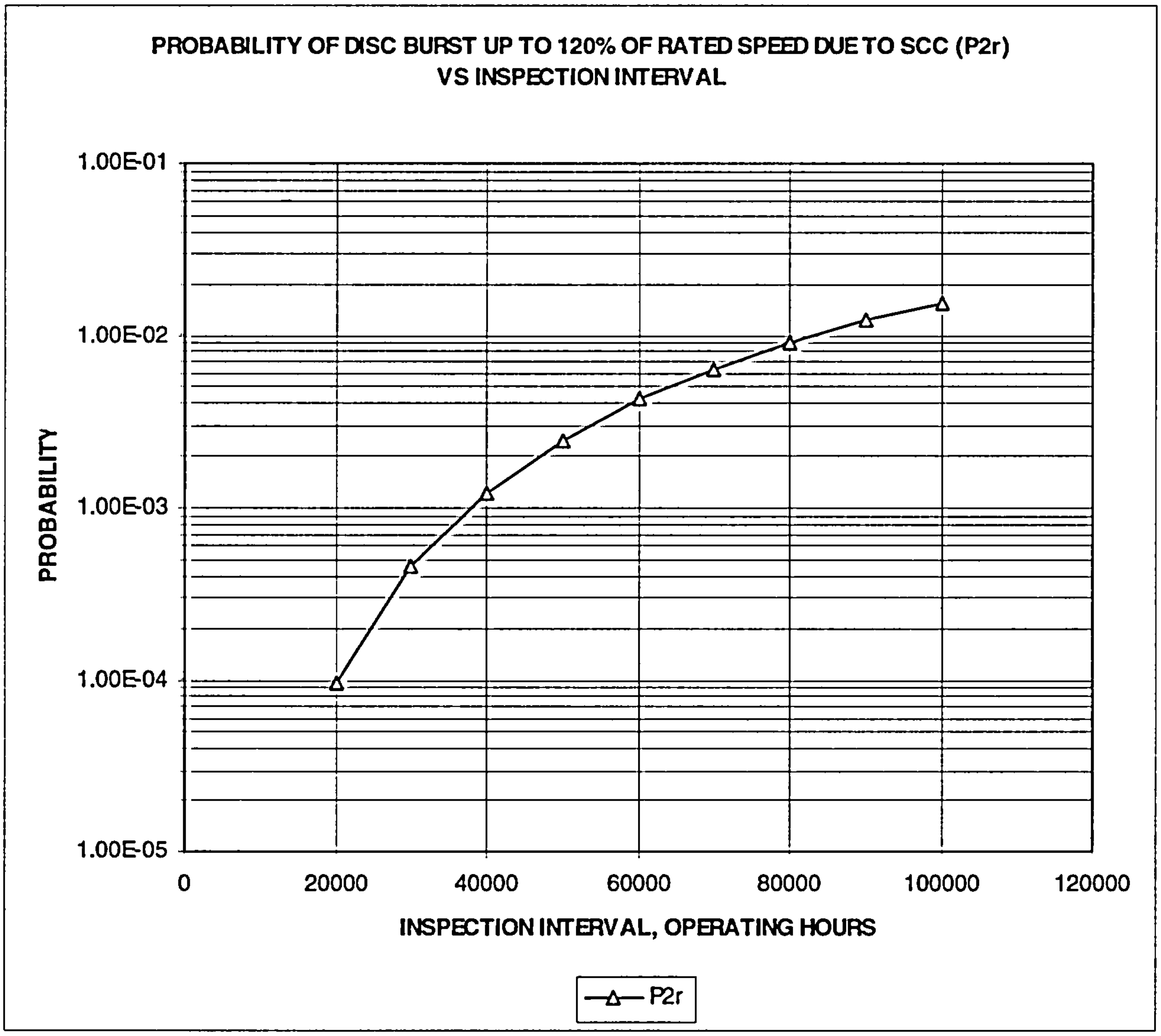


FIGURE 12

13.9 m^2 DESIGN

DISC BURST PROBABILITY AT NORMAL OPERATION UP TO 120% SPEED
VS INSPECTION INTERVAL



7 CONSERVATISM IN METHODOLOGY

Some conservatism's used in this report's assumptions and analysis are:

1. Residual compressive stresses introduced during manufacturing are conservatively assumed to be about –100 MPa. Figure 7 shows more realistic values of compressive residual stresses, which are much higher. The shrink fit and centrifugal stresses during normal operation, when combined with residual compressive stresses will reduce the final stresses to well below the threshold for stress corrosion cracking.

2. The crack initiation probabilities are based on the "old approach", which is applicable to ten and eight disc designs. Crack initiation probabilities could have been based on the "modern approach" with more up to date crack initiation data. This would have significantly lowered the probabilities.

3. Westinghouse crack growth rates are used in the analysis. These crack growth rates are the most conservative available.

4. The probability of achieving speeds up to 120% of rated speed during normal operating conditions is conservatively assumed to be 1.0. More realistically, the probability of achieving speeds from 100% up to 120% of rated speed is a small value typically less than about 2E-3. Speeds exceeding 107% to 110% by control system design are uncommon. Speeds above 100% are limited by generator synchronization.

5. The missile probability up to 120% speed and burst capability curves shown in Figures 11 and 12 are conservative at inspection intervals approaching 100,000 operating hours since they essentially represent the probability of a crack size exceeding 100 mm and not necessarily failure as discussed in section 3.4.

6. The probabilities of both burst and casing penetration for a run-away overspeed event greater than 120% of rated speed are conservatively set to be 1.0 for all discs. In reality, only the heaviest pieces with the worst geometry at significantly higher than 120% speed would penetrate the casing below the final burst speed. And then even less that 50% of those missiles would be thrown upward as downward trajectory missiles would impact balance of plant equipment only, such as the condenser.

8 REFERENCES

[1] "Engineering Report ER-8402, "Probability of Disk Cracking Due to Stress Corrosion -- Comanche Peak Unit 1", Utility Power Corporation Proprietary Information, August 1984.

[2] "Engineering Report ER-8605a, "Probability of Disk Cracking Due to Stress Corrosion - Connecticut Yankee Replacement LP Rotors", Utility Power Corporation Proprietary Information, July 1986, Rev A, June 1987.

[3] "Engineering Report ER-8611, "Turbine Missile Analysis for 1800 rpm Nuclear LP-Turbines with 44-inch Last Stage Blades", Utility Power Corporation Proprietary Information, July 1986, Rev 1, June 1987.

[4] "Engineering Report ER-8503, "Probability of Disk Cracking Due to Stress Corrosion -- Grand Gulf Unit 1", Utility Power Corporation Proprietary Information, March 1985.

[5] "Energy Analysis in the Hypothetical Case of a Wheel Disk Burst in the LP Sections 1 to 3 of the New Design Series - Nuclear Power Plant Grand Gulf, 7153", Siemens Power Corporation Proprietary Information, June 1995.

[6] "Engineering Report ER-98044j, "Missile Analysis with LP Upgrade Grand Gulf Nuclear Unit No. 1", Proprietary Information of Siemens Fossil Power Corporation, November 1998.

[7] U.S. Nuclear Regulatory Commission, Regulatory Guide (RG) 1.115, U.S. Nuclear Regulatory Commission, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants", July1981.

[8] U.S. Nuclear Regulatory Commission NUREG - 1048 including Appendix U & Table U.1.

[9] ABAQUS/Standard, HKS, 2001.

[10] W. G. Clark etc., ASME Paper "Procedures for Estimating the Probability of Steam Turbine Disc Rupture from Stress Corrosion Cracking", October 4-8, 1981.

[11] "Missile Probability Analysis Methodology for Limerick Generating Station, Unit 1&2 with Siemens Retrofit Turbines", June 18, 1997.

[12] "NN : Probability of Missile Generation in General Electric Nuclear Turbines – Supplementary Report: Steam Valve Surveillance Test Interval Extension – Non-proprietary Version GET-8039.1, September 1993.

[13] Ornstein, H. L.: "Operating Experience Feedback Report – Turbine-Generator Overspeed Protection Systems", U.S. Nuclear Regulatory Commission Report, NUREG-1275, Vol. 11, 1995.

[14] W. David, J. Ewald, F. Schmitz: „Grenzbelastungen zur Vermeidung von Spannungsrißkorrosion an ferritischen Rotorwerkstoffen", VGB-Konferenz „Korrosion und Korrosionsschutz in der Kraftwerkstechnik", 29. und 30. November 1995, Essen.

[15] W. David, J. Ewald, F. Schmitz: „Grenzbelastungen zur Vermeidung von Spannungsriß-korrosion an ferritischen Rotorwerkstoffen", Korrosionsschäden in Kraftwerken, 9. VDI Jahrestagung Schadensanalyse, 1. und 2. Oktober 1997, Würzburg.

[16] Letter from Mr. Bartholomew C. Buckley, NRC Senior Project Manager to Mr. George A Hunger, Jr., PECO Energy Company Director of Licensing, dated February 3, 1998, Subject: Limerick Generating Station (LGS), Units 1 and 2 of Main Turbine Rotor Replacement, Extension of Turbine Rotor Inspection Intervals and Valve Testing Frequencies (TAC Nos. M99341 and M99342).

[17] „Safety Evaluation of the Submittal to Replace Turbine Rotors at the Limerick Generating Station Units 1 and 2", NRC Docket Nos. 50-352 and 50-353.

[18] Letter from Mr. Herbert N. Berkow, NRC Director, to Mr. Stan Dembkoski, SWPC Director, dated July 22, 2003, Subject: Safety Evaluation for Acceptance of Referencing the Siemens Westinghouse Topical Report, "Missile Analysis Methodology for General Electric (GE) Nuclear Steam Turbine Rotors by the Siemens Westinghouse Power Corporation (SWPC)", TAC No. MB5679.

[19] Safety Evaluation by the Office of Nuclear Reactor Regulation, Siemens Westinghouse Topical Report "Missile Analysis Methodology for General Electric (GE) Nuclear Steam Turbine Rotors by the Siemens Westinghouse Power Corporation (SWPC)", Project 721.

APPENDIX A

SWPC SUBMITTAL LETTER

MARCH 5, 2003

SIEMENS
Westinghouse

March 5, 2003

Mr. Brian Benney
Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Document Processing Center, Mail Stop 07E1
United States Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Siemens Westinghouse Power Corporation Topical Report Submittal, "Missile Probability Analysis of BB81/281 13.9m^2"

Dear Sir:

Missile probability analysis is presented for the Siemens 13.9m^2 retrofit design of LP turbine (See Enclosure 1). These modern upgraded designs are used in various applications including replacement of Westinghouse original BB81 and BB281 nuclear LP rotors and internals.

Results of the P_1 analysis indicate that the missile probabilities remain well below the Nuclear Regulatory Commission (NRC) limits of 1E^{-4} for a favorably oriented unit and 1E^{-5} for an unfavorably oriented unit for up to 100,000 operating hours between disc inspections providing that no cracks are detected in the discs. Previously, in the Siemens submittal for the Limerick unit (See Enclosures 2 and 3), the NRC had approved the missile analysis methodology for 10 years, which is about 87,600 operating hours. The subject report justifies external missile probabilities out to 100,000 operating hours in comparison with the NRC limits.

We request NRC review and approval of the 100,000 operating hour inspection interval for Siemens LP retrofits with shrunk-on rotor discs and modern upgraded features as typically described for this 13.9m^2 design.

I have mailed one copy of the reports to Document Processing Center and the second copy directly to Brian Benney. Should you have any questions or need for additional information, please contact the writer.

Regards,

Peter Bird
Field Service Engineering S326
Siemens Westinghouse Power Corporation

Siemens Westinghouse Power Corporation
A Siemens Company

4400 Alafaya Trail
Orlando, FL 32826-2399

NRC Topical Report.doc

SIEMENS
Westinghouse

Phone: (407) 736-4686

Enclosures:

1. "Missile Probability Analysis of BB81/281 13.9m^2", by Dr. A. Bagaviev and P. Bird, February 26, 2003, CT-27332, Siemens Westinghouse Restrictive.
2. Letter from Mr. Bartholomew C. Buckley, NRC Senior Project Manager to Mr. George A. Hunger, Jr., PECO Energy Company Director of Licensing, dated February 3, 1998, Subject: Limerick Generating Station (LGS), Units 1 and 2 of Main Turbine Rotor Replacement, Extension of Turbine Rotor Inspection Intervals and Valve Testing Frequencies (TAC Nos. M99341 and M99342).
3. "Safety Evaluation of the Submittal to Replace Turbine Rotors at the Limerick Generating Station Units 1 and 2", NRC Docket Nos. 50-352 and 50-353.

cc: James McCracken S326
Jim Auman S326
Andreas Feldmueller S327
Dr. Albert Bagaviev S321

Siemens Westinghouse Power Corporation
A Siemens Company

4400 Alafaya Trail
Orlando, FL 32826-2399

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APPENDIX B

NRC ACCEPTANCE OF SUBMITTAL LETTER

APRIL 7, 2003

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 7, 2003

Mr. Peter Bird
Siemens Westinghouse Power Corporation
4400 Alafaya Trail
Orlando, FL 32826-2399

SUBJECT: ACCEPTANCE OF THE MISSILE PROBABILITY ANALYSIS OF BB81/281 13.9m^2 BY SIEMENS WESTINGHOUSE POWER CORPORATION (SWPC) FOR REVIEW (TAC NO. MB7964)

Dear Mr. Bird:

The NRC staff has performed an acceptance review of the Missile Probability Analysis of BB81/281 13.9m^2 by SWPC. The NRC staff has found that the material presented is complete enough to begin a review. The staff expects to complete its review by February 1, 2004, and estimates that the review will require approximately 200 staff hours.

Section 170.21 of Title 10 of the Code of Federal Regulations requires that topical reports are subject to fees based on the full cost of the review. You did not request a fee waiver; therefore, staff hours will be billed accordingly. To enable us to complete this review on schedule, close and frequent communications between our technical staffs will be required.

Sincerely,

Brian Benney, Project Manager, Section 2
Project ~~Directorate~~ IV
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 721

cc: See next page

cc:

Mr. Chuck Patrick, Manager
Steam Turbine Marketing
Siemens Westinghouse Power Corporation
4400 Alafaya Trail, MC653
Orlando, FL 32826-2399

Mr. Stan Dembkowski, Director
Operating Plant Services
Siemens Westinghouse Power Corporation
4400 Alafaya Trail, MC650
Orlando, FL 32826-2399

APPENDIX C

RAI RESPONSES LETTER

SUBMITTED AUGUST 8, 2003

[COPY OF RESPONSES NOT PROVIDED] [b,c]

SIEMENS
Westinghouse

August 8, 2003

Mr. Brian Benney
Project Manager, Section 2
Project Directorate IV
Division of Licensing Project Management
Document Processing Center, Mail Stop 07E1
United States Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Siemens Westinghouse Power Corporation, "Missile Probability Analysis of BB81/281 13.9m^2", TAC No. MB7964.

Dear Brian:

Attached please find RAI questions submitted by the NRC for the BB81/281 13.9m2 missile analysis and responses provided by Siemens Westinghouse (Attachment 1). One of the questions was answered by providing a technical paper recently prepared on the benefit of compressive residual stresses for nuclear rotor discs. This paper is included as Attachment 2.

The original Topical Report we submitted, CT-27332 Revision 0, has been revised to be in full compliance with the NRC recommendations in the Safety Evaluation (SE) report. This revised report CT-27332 Revision 2 is enclosed as Attachment 3.

Regards,

Peter Bird

Peter Bird
Field Service Engineering S326
Siemens Westinghouse Power Corporation
Phone: (407) 736-4686

Enclosures:

1) RAI for Topical Report, "Missile Probability Analysis of BB81/281 13.9m2", Siemens Westinghouse Power Corporation, Response Submitted August 8, 2003.
2) Walter David, Dr. Andreas Feldmueller, Dr. Heinrich Oeynhausen, "Shrunk on Disk Technology in Large Nuclear Power Plants – the Benchmark against Stress Corrosion Cracking", to be

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presented at the Parsons Conference, September 16-18, 2003, Dublin, Ireland, Siemens Power Generation.

3) "Missile Probability Analysis for BB81/281 13.9m2", by P. Bird and Dr. A. Bagaviev, August 8, 2003, CT-27332 Revision 2, Siemens AG – Power Generation.

cc: James McCracken S326
Jim Auman S326
Andreas Feldmueller S327
Dr. Albert Bagaviev S321

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..DA-040607.
..PA- 48 p. 19 refs. 12 Illus.
..DT-REPORT.
..KW-MISSILE. NUCLEAR. LP ROTORS. NRC. 13.9M^2 DESIGN
..AB- This Topical Report is required by the NRC to document the Siemens submittal of the missile report prepared for the 13.9m^2 retrofit design of Siemens LP turbine. Results of the analysis indicate that the missile probabilities remain well below the Nuclear Regulatory Commission (NRC) limits of 1E-4 for a favorably oriented unit and 1E-5 for an unfavorably oriented unit for up to 100,000 operating hours between disc inspections providing that no cracks are detected in the discs. This report justifies external missile probabilities out to 100,000 operating hours in comparison with the NRC limit. For Public Record.

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