Station Support Department

PECO NUCLEAR
A Unit of PECO Energy

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February 4, 1998

Docket Nos. 50-352
50-353

License Nos. NPF-39
NPF-85

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Subject: Limerick Generating Station, Units 1 and 2
Non-Proprietary Documentation Supporting
Replacement of Main Turbine Rotors

Dear NRC Officials:

By letter dated July 25, 1997, PECO Energy submitted documentation to the NRC regarding a planned plant modification at Limerick Generating Station (LGS), Units 1 and 2, to replace the high pressure (HP) and low pressure (LP) turbine rotor assemblies on the Main Turbines. The new turbine rotor assemblies were designed and manufactured by Siemens Power Corporation. The new advanced turbine rotors will replace the existing three (3) LP turbine rotors and one (1) HP turbine rotor on each unit's Main Turbine at LGS. In our July 25, 1997 submittal, we identified that a number of the attachments contained information of a proprietary nature to Siemens Power Corporation. Therefore, in accordance with the requirements of 10 CFR 2.790(a)(1)(i)(4), we requested that the pertinent documentation be withheld from public disclosure since it contained information involving trade secrets and commercial or financial information considered to be privileged or confidential. An affidavit was prepared by Siemens Power Corporation in support of this request and submitted in accordance with the requirements of 10 CFR 2.790(b)(1).

PECO Energy recently obtained non-proprietary versions of the documentation previously submitted in our July 25, 1997, letter. 10 CFR 2.790(b)(1)(ii) stipulates that "the information sought to be withheld shall be incorporated, as far as possible, into a separate paper." Therefore, we are submitting the non-proprietary information, since separate documents which contained proprietary and non-proprietary information had not been prepared at the time of our July 25, 1997, submittal. An affidavit, from Siemens Power Corporation, is also enclosed to support the submittal of the non-proprietary documentation. In addition, PECO Energy is also resubmitting the non-proprietary information that was contained in Attachment 1 ("Modification Summary") of our July 25, 1997, submittal. Therefore, this letter forwards the applicable non-proprietary documentation in support of this plant modification.

If you have any questions or require additional information, please do not hesitate to contact us.

Very truly yours,

D. B. Helker /for

Director - Licensing

Attachments
Enclosure

cc: H. J. Miller, Administrator, USNRC, Region I (w/ attachments, enclosure)
A. L. Burritt, USNRC Senior Resident Inspector, LGS (w/ attachments, enclosure)

ENCLOSURE

Siemens Power Corporation
Affidavit

AFFIDAVIT

STATE OF WISCONSIN

COUNTY OF MILWAUKEE

Lamont J. Jenkins being duly sworn, hereby say and depose:

1. I am Vice President, Turbine Services, for Siemens Power Corporation, (SPC), and as such I am authorized to execute this Affidavit.

2. I am familiar with SPC's detailed document control system and policies which govern the protection and control of information.

3. I am familiar with Engineering Report ER-9605NP "Missile Probability Analysis Methodology for Limerick Generating Stations, Units 1 & 2 with Siemens Retrofit Turbines" Revision No. 2, dated January 9, 1998. This report was compiled at the request of PECO Energy, intended for use in the evaluation and disclosure to interested parties, of the contained information. Proprietary information as been removed and restated to allow the intended audience better understanding of its content.

4. The information in this document is the property of Siemens Power Corporation and may not be copied or communicated to a third party, or uses, for any purpose other than that for which it is supplied without the express written consent of Siemens Power Corporation.

THAT the statements made hereinabove are, to the best of my knowledge, information, and belief, truthful and complete.

FURTHER AFFIANT SAYETH NOT.

Lamont Jenkins

SUSCRIBED before me this 21

day of January, 1998

Barbara J Sanders

NOTARY PUBLIC STATE OF FLORIDA
OFFICIAL NOTARY SEAL
BARBARA JO SANDERS
COMMISSION NUMBER
CC651194
MY COMMISSION EXPIRES
MAY 28,2001

ATTACHMENTS

Non-Proprietary Documentation

MODIFICATION SUMMARY

Limerick Generating Station
Units 1 and 2
Main Turbine Rotor Replacement

Modification Summary

DISCUSSION

Each unit at the Limerick Generating Station (LGS) was originally provided with one (1) tandem compound Main Turbine-Generator furnished by the General Electric Company (GE). Each GE Main Turbine-Generator consists of one double flow high pressure (HP) turbine section and three (3) double flow, low pressure (LP) sections. Each is a nonreheat turbine, 1800 RPM, with 38 inch last stage buckets, exhausting to a multipressure condenser. The turbine was furnished with six extraction points; one HP section extraction, one cross-around piping extraction, and four (4) LP section extractions. The cross-around piping also delivers steam to six (6) vertical moisture separator vessels of the nonreheat type for return of steam to the LP turbines, and steam to three (3) Reactor Feed Pump Turbines.

This plant modification is designed to support the replacement of the high pressure (HP) and low pressure (LP) turbine rotor assemblies on the Main Turbines at LGS, Units 1 and 2. The new replacement turbine rotors are being designed and manufactured by Siemens Power Corporation (SPC). The new turbine rotors will replace the three (3) LP rotors and one (1) HP rotor which were manufactured and installed by General Electric (GE) on each unit. The replacement LP rotors are a "shrunk-on-disk" design. The HP rotor is a "monoblock" design. SPC has provided a new methodology for analyzing missile generation probability which considers the design of the replacement rotors in combination with the existing GE turbine control system.

This proposed plant modification is scheduled to be installed on LGS Unit 1 during 1RO7 (scheduled for April 1998) and LGS Unit 2 during 2RO5 (scheduled for April 1999). Implementation of this plant modification will help to minimize the overall impact on the LGS Operations staff, in that, the extension of the interval between inspections required by the maintenance program will result in fewer load drops, and a resulting decrease in potential for operator error and reactivity management concerns. In addition, the Siemens turbine rotors are a proven design in Europe and the United States with many years of successful operating experience.

NRC General Design Criterion 4, "Environmental and Missile Design Bases," of Appendix A to 10CFR50 requires, in part, that structures, systems, and components important to safety be appropriately protected against the effects of missiles that might result from failures, such as high energy missiles resulting from a steam turbine failure. The NRC evaluation of the effects of turbine failure on the public health and safety has generically followed the guidance stipulated in Regulatory Guide (RG) 1.115, "Protection Against Low-Trajectory Turbine Missiles," and the NRC Standard Review Plan (SRP), i.e., NUREG-0800, Sections 10.2, 10.2.3, and 3.5.1.3. According to NRC guidelines stated in RG 1.115, the probability of unacceptable damage from turbine missiles (P4) should be less than or equal to 1×10^{-7} per year for an individual plant. In order to maintain P4 less than 1×10^{-7}, the NRC requires licensees to ensure that the probability of generating a turbine missile (P1) satisfies turbine reliability requirements criteria. For an "unfavorably oriented turbine," such as the LGS, Units 1 and 2, Main Turbines, the probability of generating a turbine missile (P1) is required to be less that 1×10^{-5} per year as documented in NUREG-0991, "Safety Evaluation Report Related to the Operation of Limerick Generating Station, Units 1 and 2."

In order to assure that the turbine missile generation probability (P1) follows the turbine reliability criteria, the NRC requires applicable licensees to maintain a Turbine System Maintenance Program (TSM Program), including Low Pressure (LP) Turbine inspection intervals based on manufacturer's calculation of missile generation probabilities. Both NUREG-0991 (Section 3.5.1.3) and the Unit 1 Operating License (Section 2.C.9) required that such a TSM Program, which meets the guidance stipulated in the NRC SRP and RG 1.115, be submitted to the NRC for review and approval. The current LGS TSM Program was approved by the NRC, as documented in NUREG-0991, Supplement 8, and letters from the NRC dated November 3, 1987, and May 9, 1989, and was based on the GE Turbine Missile Generation Probability Analysis Methodology and criteria documented in NUREG-1048, "Safety Evaluation Report for the Operation of Hope Creek Generating Station," Supplement 6.

The industry experience of LP turbine component failures due to stress corrosion cracking has led PECO Energy to take a proactive approach to assure that significant stress corrosion cracking (SCC) problems at LGS are not encountered. This plant modification will replace both LP turbine rotors (three each) on the LGS, Units 1 and 2, Main Turbines in order to correct and/or prevent distress. In addition, this modification will replace HP turbine rotors on the Main Turbines based on the associated cost benefit.

Since the LP turbines are a "shrunk-on-disk" design, Limerick Generating Station will be required to maintain a TSM Program. The replacement LP turbines will meet or exceed the original equipment design, manufacturing, and inspection criteria evaluated and accepted by the NRC as documented in NUREG-0991 and NUREG-0991, Supplement 8. Therefore, the replacement turbines will meet the acceptance criteria delineated in the NRC's SRP.

SPC has provided a methodology (Attachment 3) for analyzing missile generation probability that addresses the design of the replacement LP turbines in combination with the existing GE Main Turbine Control System. Attachment 2, "Missile Probability Analysis Overview" is provided to highlight the SPC design features and overall conservatisms which were incorporated into the SPC methodology. Use of the SPC methodology in support of the LGS TSM Program ensures continued compliance with the guidance of RG 1.115 and ultimately, GDC 4. The basic principles of the SPC methodology (Attachment 3) are the same as those used in previous SPC studies (including Grand Gulf, Comanche Peak, and Connecticut Yankee) that have been reviewed and accepted by the NRC. The methodology addresses the same three (3) major components that were considered by the GE methodology and accepted by the NRC as documented in NUREG-1048. These three (3) components are:

1. probability of turbine overspeed,
2. wheel burst probability, and
3. probability of casing penetration.

The LGS TSM Program utilizes a "probabilistic approach" to determine required intervals for inspection and maintenance/replacement of the LP turbines. The original GE missile generation analysis limited inspection intervals to 6 years. The current TSM Program reflects the 6-year inspection interval, except for a one-time exception on Unit 1's "B " and "C" LP turbines rotors as documented in an NRC letter dated January 2, 1996. The SPC methodology (Attachment 3) evaluates inspection intervals up to 100,000 hours (approximately 12 years). The proposed change to the LGS TSM Program limits the maximum inspection interval to 10 years, which satisfies the criteria delineated in SRP Section 10.2.3.

The TSM Program also includes required intervals for performing in-service testing of the Main Turbine Stop Valves, Control Valves, and Combined-Intermediate Valves as documented in NUREG-0991 and NUREG-0991, Supplement 3. The test intervals are also listed as surveillance requirements in Section 3/4.3.8 of the LGS, Units 1 and 2, Technical Requirements Manuals (TRMs). Currently, the Main Turbine Stop and Combined-Intermediate Valves are tested once per week. The Main Turbine Control Valves are tested once per month. The test intervals are TSM Program and TRM requirements since they provide inputs to the current GE missile generation probability analysis regarding the reliability of the Main Turbine overspeed protection system. Performance of the valve testing at the stated intervals supports the current LP turbine inspection intervals, and therefore, the probability of a turbine missile is less than 1×10^{-5} per year.

The SPC methodology (Attachment 3) evaluates a maximum test interval of 3 months for Main Turbine Stop Valves, Control Valves, and Combined-Intermediate Valves. Based on the assumptions in the SPC methodology, the valve test intervals support LP turbine inspection intervals of 100,000 hours and maintains the probability of turbine missiles less than 1×10^{-5} per year. Extension of valve test intervals based on missile generation probability has previously been accepted by the NRC as indicated in NUREG-0991, Supplement 3, Section 10.2.

Since the proposed changes to the TSM Program deviate from previously approved commitments associated with the implementation of the TSM Program and its basis (i.e., the missile probability analysis methodology), the SPC Missile Probability Analysis Methodology and the proposed changes to the present TSM Program are being submitted to the NRC for review and acceptance.

SAFETY DISCUSSION

The proposed changes do not alter LGS's conformance to RG 1.115 and GDC 4. Additionally, the proposed changes do not impact any Technical Specifications (TS) Limiting Condition for Operation (LCO) or Surveillance Requirement (SR).

Replacement of the turbine rotors on the Main Turbines requires use of the Siemens' Missile Probability Analysis Methodology (Attachment 3) to support the Turbine System Maintenance Program (TSM Program) at LGS. The current TSM Program was based on the GE Turbine Missile Generation Probability Analysis Methodology and information contained in NUREG-1048. The LGS turbine system design will continue to satisfy the guidance of RG 1.115 and requirements of GDC 4, with regards to turbine missile generation.

The maximum interval between LP turbine inspections will be limited to 10 years of operation, which is consistent with the criteria delineated in the NRC SRP. The maximum intervals for turbine valve testing will be revised to once every 3 months.

The replacement of the Main Turbine rotor assemblies will not alter the assumed function, failure modes, or reliability of the retained GE Overspeed Protection Systems. As a result, performance of the periodic operational verifications that are inputs to the GE Missile Generation Probability Methodology will be maintained for the application of the Siemens Missile Probability Analysis Methodology. In addition, the method of testing as specified in NUREG-0991, Supplement 3, Section 10.2, and periodic inspection of the turbine stop valves, control valves, combined-intermediate valves, and extraction check valves as delineated in NUREG-0991 and NRC letters dated November 3, 1987 and May 9, 1989, are unchanged by the proposed revisions to the present Turbine System Maintenance Program.

The Siemens' Missile Probability Analysis Methodology (Attachment 3) supports the installation of replacement turbines that are being designed, manufactured, and inspected to meet or exceed the quality of the original installed equipment.

Currently, there are no LGS specific accidents evaluated in the Safety Analysis Report (SAR) for the effects of turbine generated missiles. Implementation of the plant modification will continue to ensure that the probability of generating a turbine missile is maintained less than the current NRC accepted limit of 1×10^{-5} per year. Meeting this requirement assures compliance with GDC 4 , and precludes the necessity of evaluating any specific accident as a result of turbine generated missiles as referenced in NUREG-0991.

The Main Turbines and their overspeed protection systems are not safety-related and perform no safety function. Replacement of the turbine rotors will not alter, degrade, or prevent the response of active or passive components of this system from functioning as originally designed.

The issue of turbine rotor integrity has been addressed generically by the NRC's establishment of a limit on turbine missile generation such that the probability of unacceptable damage from turbine missiles should be less than or equal to 1×10^{-7} per year, as specified in RG 1.115 , in order to meet the requirements of GDC 4. To accomplish this, the probability of generating a turbine missile must be maintained less than 1×10^{-5} per year as indicated in NUREG-0991. The replacement of the turbine rotors will continue to maintain the turbine missile generation probability less that the limit specified by the NR.. as documented in NUREG-0991 and NUREG-099 ...pplement 8

Replacement of the turbine rotors will not alter, degrade, or prevent the response of Equipment Important to Safety. NUREG-0991, Section 10.2 , does describe the "turbine control system" as "important to the overall safe operation of the plant." The <u>function</u> of the control system related to overall plant safety is to provide overspeed protection to minimize the probability of generation of turbine missiles, in accordance with the requirements of GDC 4. Revising the test intervals for the valves does result in an ...crease, above that for the current valve test intervals, in the probability of a turbine overspeed event assumed in the Siemens Missile Probability Analysis Methodology (Attachment 3). Although this individual probability value has increased, the overall probability of a turbine generated missile is maintained less than the limit of 1×10^{-5} per year (refer to Attachment 3) as required to meet GDC 4.

Replacement of the turbine rotors and extension of the valve testing frequency will not adversely affect the function or failure modes of any Equipment Important to Safety . Therefore, the consequences of a malfunction of any Equipment Important to Safety remain unchanged. The Siemens' Missile Probability Analysis Methodology (Attachment 3) has demonstrated that the probability of a turbine generated missile is less than 1×10^{-5} per year which is the limit specified in NUREG-0991. As a result, the probability of "unacceptable damage from turbine missiles" is maintained less tha... equal to 1×10^{-7} per year for an individual plant, as stipulated in NUREG-0991 and RG 1.115. This plant modification will continue to ensure compliance with the requirements of GDC 4 with regards to the possibility of "internal missiles" generated by a catastrophic turbine-generator failure.

MISSILE PROBABILITY ANALYSIS OVERVIEW

MISSILE PROBABILITY ANALYSIS OVERVIEW

1.0 EXECUTIVE SUMMARY

SPC has provided an updated missile probability analysis methodology (Engineering Report ER 9605, Reference 1) to account for the SPC retrofitted turbine design as it interfaces with GE overspeed controls (not being modified), and a revised turbine maintenance program to maintain/provide the bases for the probability analysis inputs and assumptions. With a few exceptions, the basic principle of the methodology used within SPC's report are the same as those used in previous SPC studies reviewed and accepted by the NRC, which include Grand Gulf, Comanche Peak, and Connecticut Yankee. The exceptions unique to the Limerick analysis are:

1. The probabilities will support an initial rotor inspection interval of 100,000 operating hours while implementing a Quarterly/Quarterly/Quarterly valve test program,

2. A numerical Monte Carlo simulation technique has been developed and utilized for probabilistic computations as a simpler and more versatile technique for probability analyses which allows the use of more simulation cycles for determining the probability of a missile due to burst, and

3. Integration of the existing GE turbine overspeed controls and protection failure probabilities, as related to valve test frequency, into SPC's missile probability analysis methodology.

The results of the application of the Siemens methodology for determining missile probability for Limerick Generating Station is illustrated in Figure 1. This exhibit shows that the missile probability is maintained within the NRC acceptance limit of 1E-5 per year for a 10 year inspection interval (87,600 hours) and a Q/Q/Q valve testing frequency.

2.0 MODIFICATION OVERVIEW

Each unit at the Limerick Generating Station (LGS) was originally provided with one tandem compound Main Turbine-Generator furnished by the General Electric Company (GE). Each Main Turbine-Generator consisted of one double flow, high pressure (HP) turbine section and three double flow, low pressure (LP) sections. Each is a nonreheat turbine, 1800 RPM, with 38 inch last stage buckets, exhausting to a multipressure condenser. The turbine was furnished with six extraction points; one HP section extraction, one cross-around piping extraction, and four LP section extractions. The cross-around piping also delivers steam to six vertical moisture separator vessels of the nonreheat type for return of steam to the LP turbines, and steam to three Reactor Feed Pump Turbines.

The primary objective of this modification is to redesign and replace existing high pressure (HP) section steam path and low pressure (LP) section turbine inner cylinders in the Unit 1 and 2 Main Turbines at LGS. The redesign including a new turbine missile probability analysis, fabrication and installation for the turbine components has been awarded to Siemens Power Corporation (SPC). SPC and Siemens/KWU will manufacture and install the advanced design turbine rotors to replace the existing three LP turbine rotors and one HP turbine rotor which were manufactured and installed as part of the GE Turbine Generator package. The Siemens LP rotors will have 46 inch last stage buckets. Many of the GE components are being maintained as part of the retrofit. It is expected that component replacements will accomplish the following:

- Mitigate Stress Corrosion Cracking (SCC) in the area of the turbine disk key-ways
- Mitigate SCC in the area of the blading attachments
- Mitigate erosion of the turbine rotating and stationary parts
- Enhance net turbine output capability by taking advantage of more efficient steam path designs
- Extend the interval between inspections required for the turbine maintenance program by utilizing improved manufacturing techniques and selection of materials.

The turbine retrofit will minimize the impact to the existing Main Turbine System equipment, components, and support systems by making use of existing material and equipment. Therefore, the interfacing equipment, components, and system functions are being retained within the design basis as described in the SAR, with only minor changes being required.

The retrofitted turbine does not require changes to the Limiting Conditions of Operation or Surveillance Requirements as specified in the Technical Specifications. However, the methods for turbine maintenance, determination of the probabilities of turbine missile generation, and Turbine Stop Valve and Turbine Control Valve test frequencies, as required by LGS SER Section 3.5.1.3, SSER 8 and the Unit 1 Operating License will require revision. This report highlights the methodology, maintenance program, and the intended valve testing frequency which is being proposed.

Other significant related changes which do not require prior NRC approval are:

1. Turbine Control Valve (TCV) control will be modified to convert the steam admission to the High Pressure turbine from partial arc admission to full arc admission. This will result in changes to the TCV mechanical stops, which affect the fast closure time of the TCVs used in various transient analyses. Reload specific analyses will be performed as part of the standard reload licensing process to establish operating limits as required to maintain the specified safety margins of the transient analyses.

2. The turbine first stage pressure measurement location will change as a result of this modification. The existing turbine design measures the parameter downstream of the turbine first stage. The SPC turbine design being installed in this modification uses the same instrumentation to measure this parameter upstream of the turbine first stage and is located on the steam pipes downstream of the TCVs. Relocating the instrument sensing location does not alter the functionality of the parameter. These instruments will maintain the same first stage terminology even though the pressure being sensed will require a different pressure setpoint. Maintaining this terminology will prevent future confusion due to the significant usage of this terminology. This parameter is used in the Reactor Protection System (RPS) as an indicator of plant power level (above or below 30% rated thermal power). The relocated instruments will be used by RPS in the same manner. The actual pressure setpoint value corresponding to 30% rated thermal power will be changed. The revised pressure source location will continue to provide the same turbine steam flow information.

3.0 DESIGN APPROACH

Siemens has continually advanced its LP turbine design from a ten disk, to the present 6 disk configuration due to improved forging processes and utilizing one disk to carry two rows of free standing blading (see Figure 4). This newly developed design provides improved thermal performance, while maintaining and enhancing the already high degree of reliability and availability of previous designs. Additionally, residual compressive stresses are induced in the entire blade attachment area. Replacement of existing turbines (Siemens or other OEM turbines) with improved six disk LP turbines results in a gain of plant power output.

Siemens newly developed six disk LP turbine significantly reduces the probability of turbine missile generation in the following ways.

a. Fewer disks reduces the miss[illegible]bability.

b. Disk Nos. 2 and 3 are not keyed, which reduces the stress concentration factor which in turn reduces the probability of disk burst due to stress corrosion cracking.

c. No. 1 disks are keyed on the down stream side of steam flow, which reduces the probability of burst due to reduced stress corrosion crack growth rates at reduced steam temperature.

d. Increased residual compressive stresses made possible due to larger disk sizes, reduce the probability of disk burst due to stress corrosion cracking.

For the existing Limerick Generating Station turbines, General Electric had performed a probability study to confirm that the likelihood of producing an external missile is below the value of 1E-5 per year. Turbine inspections at six year maximum intervals and Weekly/Monthly/Weekly (W/M/W) valve testing intervals are presently in place. Siemens Power Corporation has performed a new probability study to confirm the above probability limits are not exceeded for the retrofitted turbine even with increased turbine rotor inspection intervals of 100,000 hours and valve test frequencies changed to Quarterly/Quarterly/Quarterly (Q/Q/Q).

4.0 SIEMENS/KWU DESIGN FEATURES

Specified yield strength range below the value of 1000 MPa (145 ksi), the approximate value at which material becomes susceptible to hydrogen induced stress corrosion cracking, and thereby minimizes the material's stress corrosion crack initiation potential.

Operating stress levels are reduced by eliminating key-ways in Disks Nos. 2 and 3 and by introducing significant compressive stresses through heat treatment of the disks, shot peening of surfaces including the blade attachment area, and honing followed by rolling of key-ways in No. 1 disk. The operating stress levels at or near the surface are well below 50% of the yield strength thus virtually eliminating stress corrosion crack initiation.

Siemens disks are very robust, i.e., wide, yielding large shrink fit forces. Because of the lower temperatures on the downstream side of disk No. 1, the in-service shrink fit forces remain high allowing elimination of key-ways in the No. 2 and No. 3 disks. The shrink fit forces on No. 2 and No. 3 disks exceed their operational torque by more than ten times

No. 1 disk remains keyed as a result of the temperature profile during start up. Figure 11 illustrates the shrink fit and key-way detail configuration. Siemens key-ways are located downstream of the steam flow where the metal temperature is higher than the surrounding steam temperature. This eliminates condensation and reduces the Stress Corrosion Cracking potential. The key-way, which is round, is open circumferentially by a gap and is located in a non-shrink fit area. After rolling to induce residual stresses, the key-way is honed before the round key is fit.

The first 20% of the inlet side of disk No. 1 hub is relieved by a , while the shaft is profiled, to give a relatively large cavity eliminating the shrink fit. There is a between the front side of the disk and the rotor shaft. This allows an efficient "pumping" action due to centrifugal forces to take place which expels any moisture or impurities, thus eliminating any stagnant condition of the steam.

Siemens has used the same general blade root attachment arrangement for both drum stage and free standing blading for more than thirty years for both nuclear and fossil units. Some nuclear units are approaching 200,000 operating hours without blade attachment failure. Inspections to date have not found crack initiation in the blade attachment area of disks or rotor forgings of either nuclear or fossil units. Because nuclear unit LP disks are operating in conditions where stress corrosion cracking is possible, blade loading on disk surfaces in the present design is maintained such that the stresses are less than 50% of material yield strength. For eight disk designs, the caulking areas (the areas below the blading on the disks), were shot peened to induce compressive residual stresses to assure no crack initiation where propagation would be downward into the disk. On more recent designs, including Limerick, the radii regions of those disk blade attachment areas which are susceptible to potential SCC, are shot peened to induce compressive residual stresses to minimize operating stress levels to further assure stress corrosion cracks will not be initiated.

5.0 MISSILE PROBABILITY ANALYSIS

The most significant source of turbine missiles is a burst-type failure of one or more bladed disks of an LP rotor. Failures of other rotors including the HP and generator rotor would be contained by relatively massive and strong turbine casings, even if failure occurred at maximum conceivable over-speed of the unit. There is a remote possibility that some minor missiles could result from the failure of couplings or portions of rotors which are not enclosed within these casings. Also, failure of exciter rotating elements could produce missiles because the exciter housing is relatively light. However, both exciter and coupling missiles would be much less hazardous than the LP disk missiles, due to low mass and energy, and therefore are not considered. Compressive stresses are induced in the blade attachment area during fabrication and blade loading is limited by design to minimize the possibility of blade attachment crack initiation and blade detachment.

The probability of an external missile is evaluated as the combination of the probability of two distinct types of LP rotor disk failures; 1) failure at normal operating speed up to 120% of the rated speed due to stress corrosion cracking, and 2) failure due to run-away overspeed greater than 120% of the rated speed based on a failure of the protection system.

The basic principles of the SPC methodology are the same as previous studies which have already been reviewed by NRC (e.g., Grand Gulf, Comanche Peak, and Connecticut Yankee). However, the analysis methodology for LGS uses additional enhancements and the latest technologies to provide beneficial results to the operation of the plant.

a. Turbine rotor inspection intervals of up to 100,000 operating hours and a Q/Q/Q valve test program.

b. A Monte Carlo simulation numerical technique which has been developed by SPC for performing the probabilistic computations for generation of an external missile at speeds up to 120% of rated turbine speed. The Monte Carlo method is a highly popular, simple and versatile technique for probabilistic analysis when multiple variables are associated with different types of statistical distributions. This procedure has been used for other applications. It provides for greater accuracy and speed for the simulations of a burst which removes some of the built-in conservatism that previously existed for this analysis. Since the probability of an external missile generation at speeds up to 120% of rated turbine speed is of a much smaller magnitude than the contribution of the over-speed (>120%) event, which does not use Monte Carlo simulations, a reduction in the margin of safety for calculating missile generation due to stress corrosion cracking does not significantly affect the final margin of safety to the results of the overall analysis.

c. The methodology for integrating the failure analysis of the existing GE turbine overspeed protection system (which is not being modified) with the analysis for the SPC retrofitted turbine components is also unique to the Limerick analysis. Siemens has conservatively used values from their specific Nuclear and Fossil unit control systems which, for Q/Q/Q valve testing, provides a factor of safety of about 2 compared to the similar GE published data. This conservatism will provide sufficient time for responding to any future changes to the GE control system reliability analysis. Due to a large base of presently installed GE control systems which have accumulated many years of operational history, it is not very likely that a future reduction in reliability would be identified.

   Therefore, sufficient assurance is demonstrated that the calculated control system reliability, which is a function of GE's reliability data base, is being conservatively controlled within this "combined" analysis methodology.

Additional analysis has been performed to consider undetectable crack initiation at the first inspection. After the initial operating period, even if no indications are detected by the nondestructive examination, an initiated   is assumed to be present in each disk. The is based on Siemens ultrasonic examination resolution capability. The results, shown in Figure 2, demonstrate that this assumption has a minimal effect on the external missile probability.

6.0 OVERALL CONSERVATISMS WITHIN SIEMENS METHODOLOGY

A summary of the significant conservatism which Siemens will incorporate into the methodology are:

1. Residual compressive stresses introduced during manufacturing are

   The shrink fit and centrifugal stresses during normal operation, when combined with the residual compressive stresses, reduce the final stresses to well below the threshold for stress corrosion cracking.

2. The crack initiation probabilities which are based on the ten and eight disk designs are assumed for the new six-disk design. This is conservative because the older design disks did not have the benefit of additional compressive residual stresses of the new design. The crack initiation probability for the new six disk design is expected to be practically zero.

3. General Electric stress corrosion crack growth rates are assumed by SPC for evaluating the stress corrosion crack growth life. The GE rates are about two to four times higher than the rates predicted by the Siemens/KWU rate equation, which is based on actual experience of Siemens units.

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 this probability is a Speeds exceeding 107% to 110%, by control system design, are uncommon. Speeds above 100% are limited by generator synchronization.

5. Although not a requirement, the internal disk burst probability under normal operation up to 120% speed is less than the NRC probability limit for an external missile up to about 100,000 hours of operation between inspections, provided no cracking is detected.

6. The missile probability up to 120% speed and burst probability curves shown in Figures 2 and 3 are conservative at 120,000 hours and higher, since they essentially represent the probability of crack size exceeding 100 mm and not necessarily failure.

7. For evaluating the casing penetration probability at 120% speed, conservative mean values are used for the input variables.
significant variables is the coefficient of friction.

the estimated casing penetration probability is conservative by a factor of about 8-10.

8. The probabilities of both burst and casing penetration for a runaway over speed event >120% of the rated speed are conservatively assumed to be 1.0 for all disks. In reality, only heavy pieces with the worst geometry of the burst disk(s) at significantly higher than 120% speed would penetrate the casing below the final burst speed. Less than 50% of those missiles would be thrown upward and potentially damage safety related items; downward trajectory missiles would impact balance of plant equipment only, such as the condenser.

9.

7.0 SUMMARY AND CONCLUSIONS

The Siemens Missile Probability Analysis Methodology Report for Limerick Generating Station, Units 1 & 2, ER 9605, has been reviewed to determine that the NRC's safety objectives as defined in the General Design Criteria, GDC 4 have been met. This is based on increasing the interval for turbine rotor inspections to 10 years of operation and turbine valve testing frequencies to quarterly.

8.0 REFERENCES

1. "Engineering Report ER-9605 Missile Probability Analysis Methodology for Limerick Generating Station with Siemens Retrofit Turbines", Siemens Power Corporation Proprietary Information, Revision 2; June 18, 1997.

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