PMSTPCOL PEmails

From: Tai, Tom
Sent: Sunday, October 17, 2010 8:59 AM
To: STPCOL
Cc: Wunder, George
Subject: FW: RAI 10.2 Response Letter
Attachments: Att 5 UTLR-0008-NP corrected .pdf; Att 6 UTLR-0009-NP corrected.pdf; Att 7 - Affidavit.pdf

Tom Tai
DNRL/NRO
(301) 415-8484
Tom.Tai@NRC.GOV

From: Agles, James [mailto:jaagles@STPEGS.COM]
Sent: Friday, October 15, 2010 5:48 PM
To: Tai, Tom
Cc: Elton, Loree
Subject: RE: RAI 10.2 Response Letter

Tom,

The five Toshiba Attachments in a combined file are 13.2 Meg, so I will have to send them in two batches.

From: Agles, James
Sent: Friday, October 15, 2010 4:39 PM
To: 'Tai, Tom'
Cc: Elton, Loree
Subject: RAI 10.2 Response Letter

Tom,

I am sending you our response to the four 10.2 RAIs in two pieces as follows:

#1: The signed cover letter and four RAI responses.
#2: The Toshiba attachments with Affidavit.

It was too big to send in a single file.

Loree will complete distribution on Monday and send you a new copy with both sections combined.

Jim

Hearing Identifier: SouthTexas34Public_EX
Email Number: 2459

Mail Envelope Properties (0A64B42AAA8FD4418CE1EB5240A6FED12195631B99)

Subject: FW: RAI 10.2 Response Letter
Sent Date: 10/17/2010 8:58:42 AM
Received Date: 10/17/2010 8:58:50 AM
From: Tai, Tom

Created By: Tom.Tai@nrc.gov

Recipients:
"Wunder, George" <George.Wunder@nrc.gov>
Tracking Status: None
"STPCOL" <STP.COL@nrc.gov>
Tracking Status: None

Post Office: HQCLSTR02.nrc.gov

Files	**Size**	**Date & Time**
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Att 5 UTLR-0008-NP corrected .pdf	671735	
Att 6 UTLR-0009-NP corrected.pdf	363803	
Att 7 - Affidavit.pdf	3015088	

Options
Priority: Standard
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Sensitivity: Normal
Expiration Date:
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Technical Report

Analysis of the Probability of the Generation of Missiles from Fully Integral Nuclear Low Pressure Turbines

South Texas Project, Units 3 & 4

Approved by

J. Tominaga

Turbine Design & Assembling Dept.
Steam Turbine Engineering Group

TOSHIBA CORPORATION

KEIHIN PRODUCT OPERATION

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1. Abstract

The purpose of this report is to analyze the probability of the generation of missiles from fully integral nuclear low pressure rotors.

The potential for rotor bursting is analyzed for the low pressure turbine rotors of the South Texas Project unit 3 and 4. Four failure mechanisms are evaluated: destructive overspeed, high cycle fatigue, low cycle fatigue, and stress corrosion.

Stress corrosion is found to be the dominant mechanism for determining the potential for missile generation. Analyses show that the probability of a rotor burst by this mechanism does not exceed 10^{-5} even after [ ] years of running time. Therefore, it is concluded that periodic in-service inspections are not required for fully integral nuclear low pressure rotors to meet NRC safety guidelines.

2. Introduction

A typical steam turbine for modern nuclear power stations consists of a double-flow high pressure element and two or three double-flow low pressure elements in tandem. The rotor of the high pressure element generally consists of a single monoblock forging with blades attached in a fashion dependent upon the specific manufacturer's preference. Until recently, the large size of nuclear low pressure rotors has necessitated that they be constructed by building together a number of individual disc forgings. One typical construction method utilizes individual discs that are shrunk on and keyed to a central shaft.

Advances in the steel making industry have extended the capability to produce large ingots and forgings, and have removed the size restrictions on low pressure rotor designs. Turbine designers recognize the advantages of this new technology, and fully integral nuclear LP rotors are now designed and manufactured. Fully integral rotors are applied to LP rotors for the South Texas Project unit 3 and 4.

The purpose of this report is to assess the integrity and safety of the fully integral LP rotor designs for the South Texas Project unit 3 and 4 to establish requirements on the nature and frequency of in-service rotor inspections. This assessment is accomplished by evaluating the possibility of a rotor fracture, which leads to bursting and the generation of missiles. Where possible, the probability of a rotor burst is determined directly.

3. Design Features

A typical fully integral rotor construction is shown in Figure 3-1. A major advantage of this design compared with built-up rotors is the elimination of the disc bores and keyways. Rotors with shrunk-on discs have peak stresses at locations where the discs are keyed to the shaft. The elimination of these regions has transferred the location of peak stress from the keyways to the lower stressed blade fastening regions. To further reduce peak stresses, the blade grooves in fully integral rotors are machined with large radii. These grooves have reduced the rotor peak stresses significantly. Since the regions of peak stress are the locations where cracks are likely to initiate, this large reduction in peak stresses leads to significant reductions in the probability of a rotor burst.

An additional, equally important, benefit derived from the peak stress reductions achieved in fully integral rotors is that lower stress levels permit the use of lower strength materials while maintaining traditional factors of safety. The fully integral rotor designs utilize forgings heat treated to minimum yield strengths of approximately [ ] N/mm^2 and minimum Charpy V-notch impact energy of [ ] J, depending upon the requirements of the particular application. Many years of experience and testing of the 3.5% Ni-Cr-Mo-V alloy steel rotor material have demonstrated that the ductility, toughness, and resistance to stress corrosion cracking increase as the yield strength is decreased. These benefits give additional reductions of the probability of rotor fracture.

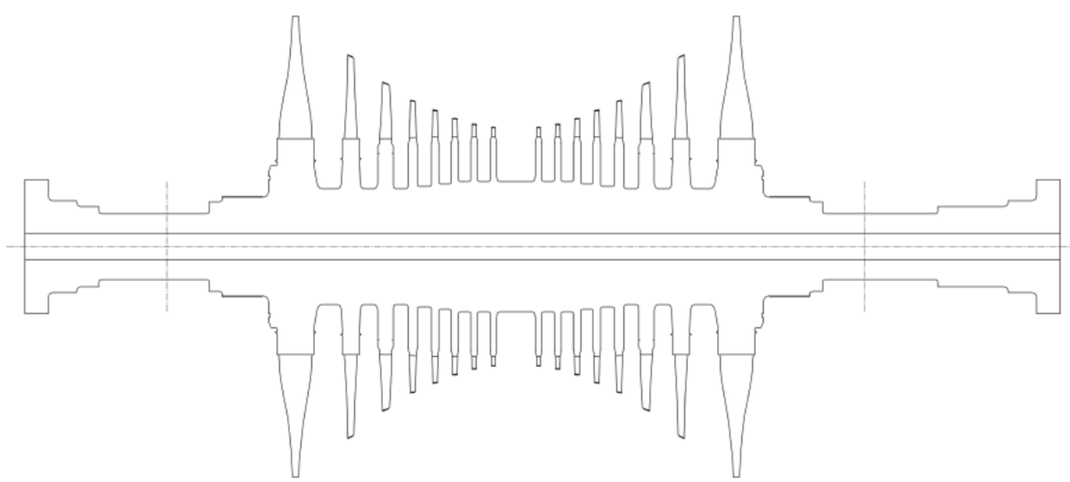


Figure 3-1 Typical Fully Integral Rotor Construction

3.1 Material Features

In addition to the increased capability to manufacture very large rotor forgings, improvements in steel making practices have resulted in products with improved toughness, uniformity of properties and reductions in undesirable embrittling elements. Table 3-1 and 3-2 show chemical composition and mechanical properties required for the LP rotor material of the South Texas Project unit 3 and 4. Specifications written for fully integral rotors incorporate these enhancements.

To confirm uniformity, the specifications for fully integral nuclear rotors require testing at the locations shown in Figure 3-2. Using these specimens, tensile and impact test are performed and are used to confirm conformity to specification requirements.

Table 3-1 Chemical Composition of LP Rotor Material (%)

C	Mn	P	S	Si	Ni	Cr	Mo	V	Cu	Al

Note: Maximum or range.

Table 3-2 Mechanical Properties of LP Rotor Material

Location of Test Piece	Tensile Strength (MPa)	Yield Strength 0.02% offset (MPa)	Elongation Gauge length 50mm (%)	Reduction of Area (%)	V-notch Charpy Absorbed Energy (J)	Transition Temperature (℃)
Radial Body						
Longitudinal Prolongation						

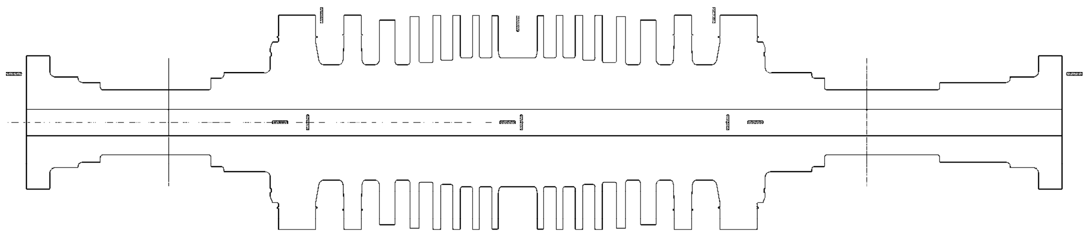


Figure 3-2 Typical Fully Integral Rotor Test Locations

4. Probability of Missile Generation

To assess the probability of missile generation resulting from the bursting of a fully integral nuclear low pressure rotor, four potential failure mechanisms are considered:

1. Ductile burst from destructive overspeed.
2. Fracture resulting from high-cycle fatigue cracking.
3. Fracture resulting from low-cycle fatigue cracking.
4. Fracture resulting from stress corrosion cracking.

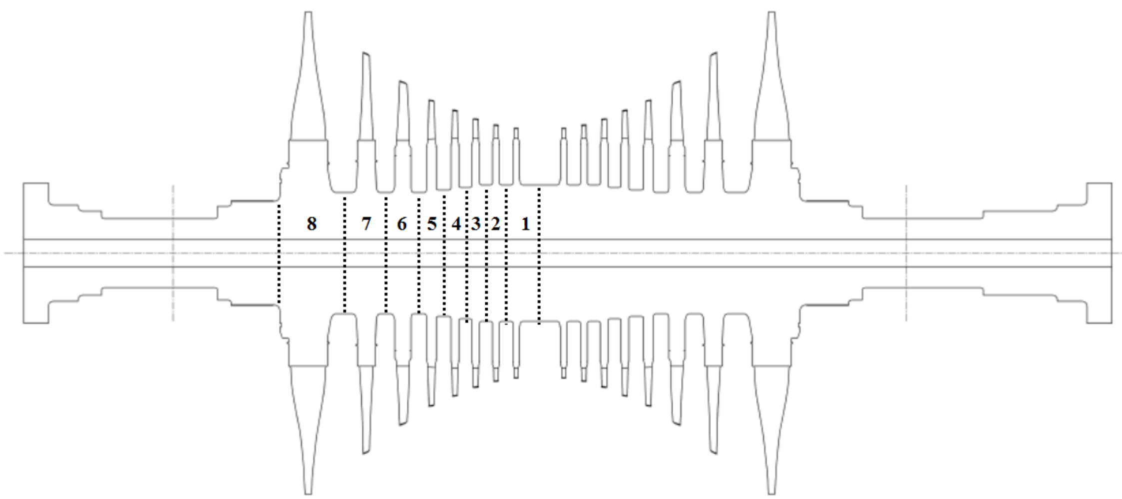
For purposes of this report, a rotor burst is considered sufficient to create a missile although it is recognized that the turbine casing offers resistance to the creation of external missiles. The methodology and results for each of the failure mechanisms analyzed are discussed in the following sections.

4.1 Ductile Burst from Destructive Overspeed

Tests have been performed by a number of investigators in which model turbine discs have been spun to failure. The results demonstrate that ductile failure can be predicted by assuming that at burst; the average tangential stress is equal to the tensile strength of the disc. By knowing the stress required for failure it is possible to calculate the speed at which failure would occur. This has been accomplished using a finite difference analysis method, wheel disc stress calculation based on [ ], which calculates the average tangential stress at any given speed. For this analysis, the integral rotor body is treated as individual discs as shown in Table 4-1. To be conservative, it is assumed that failure occurs when the average tangential stress in any individual disc equals the bore yield strength of that disc, rather than the tensile strength.

Table 4-1 Fully Integral Rotor Safety Factors Considering Ductile Bursting

Disc	Temp (°C)	Yield Strength at Temp (MPa)	Avg. Tang. Stress at Rated Speed (MPa)	Safety Factor $\frac{\text{Bore Y.S.}}{\text{Avg. Tang Stress}}$	$\frac{\text{Burst Speed}}{\text{Rated Speed}}$ $\sqrt{\frac{\text{Bore Y.S.}}{\text{Avg. Tang Stress}}}$
1	[ ]	[ ]	[ ]	[ ]	[ ]
2	[ ]	[ ]	[ ]	[ ]	[ ]
3	[ ]	[ ]	[ ]	[ ]	[ ]
4	[ ]	[ ]	[ ]	[ ]	[ ]
5	[ ]	[ ]	[ ]	[ ]	[ ]
6	[ ]	[ ]	[ ]	[ ]	[ ]
7	[ ]	[ ]	[ ]	[ ]	[ ]
8	[ ]	[ ]	[ ]	[ ]	[ ]



4.2 Fracture Resulting from High Cycle Fatigue Cracking

In this scenario, it is postulated that a failure can occur from a fatigue crack, which propagates in a plane transverse to the rotor axis as a result of cyclic bending loads on the rotor. These loads are developed by gravity forces and by possible misalignment of the bearings. Missile generation by this mechanism is highly unlikely since:

1. Large safety factors used in the design minimize the initiation and propagation of a fatigue crack.
2. A large transverse crack will create an eccentricity and the resulting high vibrations will cause the unit to be removed from service before fracture occurs.

However, to assure that rotor burst by this scenario will not occur during service operation, the following were evaluated:

1. Strength over stress ratios,
2. The likelihood of formation of a high-cycle fatigue crack, and
3. The propagation of a pre-existing crack by high-cycle fatigue.

Strength to stress ratios and the likelihood of initiating a high cycle fatigue crack are evaluated by comparing the magnitude of the bending stress with the failure stress, σ_{fail}, obtained from a Goodman Diagram and reduced to account for size effects. The safety factors obtained for three rotors are presented in Table 4-2. From this table, it is seen that the minimum safety factor at location [ ] (see figure below Table 4-2) is more than 3.0 in all three rotors. Therefore, from the viewpoint of crack initiation, these rotors have sufficient strength against high-cycle fatigue fracture.

The propagation of a postulated pre-existing crack is evaluated as follows:

The rotors have the threshold stress intensity range, ΔK_{th} , for fatigue crack propagation that is obtained from the relation:

[ ] (4.1)

where $\Delta\sigma$ is the alternating bending stress, and a is the existing crack size. The flaw shape parameter, Q, is determined by assuming semi-elliptical crack at the material surface with a depth to length ratio of about [ ]. Such a flaw crack shape parameter would be [ ] at least, independent of the stress. Therefore, Q is set to [ ], conservatively.

It is conservatively assumed that the threshold stress intensity range, ΔK_{th}, is 2.5 MPa*m$^{1/2}$ (general alloy steel) and the minimum allowable crack size, a_{min}, is [ ] mm (the assumed maximum undetectable crack size) leads to estimation of the minimum allowable vibration stress, $\Delta\sigma_{al}$, as:

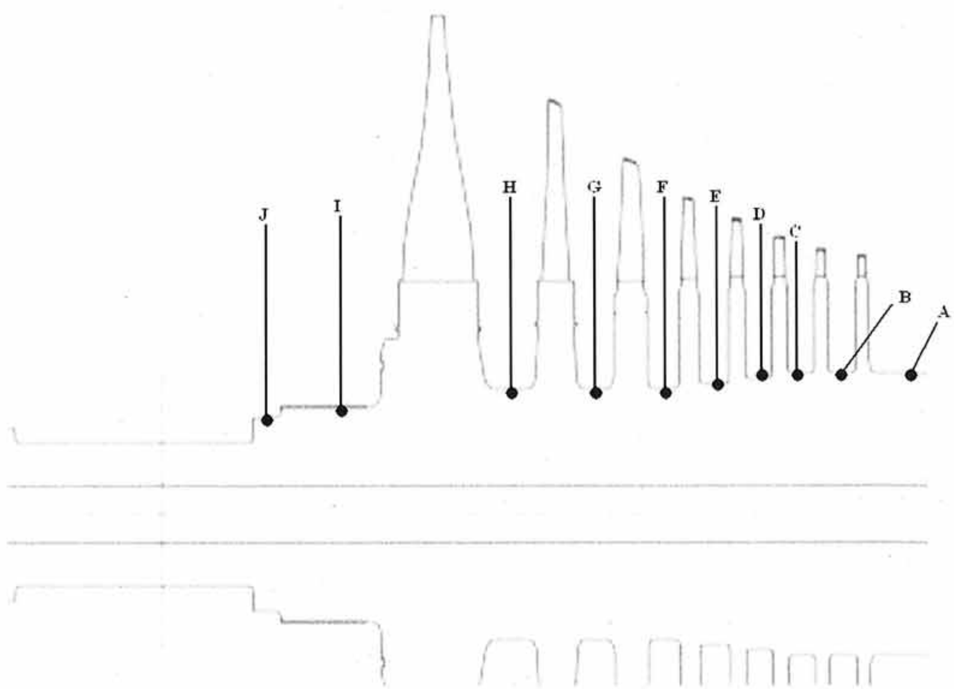
$$\Delta\sigma_{al} = [\qquad] \tag{4.3}$$

When compared to the peak stress on Table 4-2, it can be seen that all of the peak stresses, σ_{peak}, are well below [ ]. This shows that the rotors have a safety margin on the propagation of a postulated pre-existing crack.

From the above analyses, it is seen that the rotors have large safety factors against high-cycle fatigue. Therefore, concerned with the low pressure rotors of the South Texas Project unit 3 and 4, periodic in-service inspections for transverse fatigue fractures are not required.

Table 4-2 High Cycle Fatigue Peak Alternating Stresses and Safety Factors

Location	A	B	C	D	E	F	G	H	I	J
σ_{fail}, MPa										
LP-1 LP-2 LP-3	[									]
σ_{peak}, MPa										
LP-1 LP-2 LP-3	[									]
Safety Factors										
LP-1 LP-2 LP-3	[									]



4.3 Fracture Resulting from Low Cycle Fatigue – Startup/Shutdown Cycles

An analysis was carried out to determine the turbine missile generation due to a startup/shutdown cycle fatigue crack growth. In this postulated scenario, the failure mechanism is a brittle fracture, where a crack initiates in an axial-radial plane at the bore of a fully integral rotor and grows to a critical size as result of speed cycling during the operating life of the turbine.

The number of cycles to create such a failure depends on the magnitudes of and interrelationships among the following six factors:

1. The size of cracks in the bore at the beginning of turbine operation
2. The shape of these cracks
3. The size of the critical crack (dependent on the stresses experienced at running speed or design overspeed and toughness of the rotor)
4. The magnitude of the range of stress cycles experienced during the operation of machine

5&6. The two parameters, C_0 and n, in the Paris fatigue crack growth rate equation:

$$\frac{da}{dN} = C_0 \left(\Delta K\right)^n \tag{4.4}$$

where da/dN is the crack growth rate (per cycle), ΔK the stress intensity range, and C_0 and n are determined experimentally.

The number of cycles for failure, Nf, is expressed by the following equation.

$$Nf = \frac{2}{(n-2)\cdot C_0 \cdot M^{n/2} \cdot \Delta\sigma^n}\left(a_i^{-(n-2)/2} - a_{cr}^{-(n-2)/2}\right) \tag{4.5}$$

where

$M = 1.21\pi/Q$

a_i = Initial largest crack depth

a_{cr} = Critical crack depth

$\Delta\sigma$=Range of stress cycles in operation.

The flaw shape parameter, Q, is determined by assuming a semi-elliptical crack with a depth to length ratio of about [ ] formed at the bore surface, and set to [ ], conservatively.

The critical crack size, a_{cr}, is obtained from the relation:

$$a_{cr} = \frac{Q}{1.21 \cdot \pi} \left(\frac{K_{IC}}{\sigma} \right)^2 \tag{4.6}$$

where K_{IC} is the fracture toughness of the rotor and σ is the stress at operating speed and design overspeed.

The bore stress at the last stage wheel is used for the above equation, and the evaluated values are [ ] MPa and [ ] MPa, respectively, at running speed and design overspeed of 120%. The fracture toughness, K_{IC}, is taken to be [ ] MPa*m$^{1/2}$ at the last stage wheel based on the lower limit curve for the fracture toughness of the several rotor materials. This value is much less than [ ] MPa*m$^{1/2}$, which is estimated from [ ]

The size of the initial crack depth, a_i, is taken to be [ ] mm since the inspection procedures used for fully integral rotor forgings will reliably detect flaws as small as [ ] mm deep, which is considered with the depth-to-length ratio of about [ ].

The range of $\Delta\sigma$ is taken from the expected range of stress occurring during a start-up to running speed cycle.

The value of C_0 and n in the Paris fatigue crack growth rate equation are [ ] mm/cycle and [ ], respectively. These values are obtained from the upper limit curve of the fatigue crack growth rate data against the stress intensity range, ΔK kg/mm$^{3/2}$, that are composed of the several materials.

The results of the above calculation are summarized in Table 4-3. It shows that the numbers of cycles for the generation of missiles by this mechanism are extremely large. If it is assumed that the turbine operates [ ], the operation life considering this failure mechanism is [ ] Therefore, rotor burst by this scenario will not occur.

Table 4-3 Number of Cycles for Rotor Rupture Due to Startup/Shutdown Cycle Fatigue Crack Growth

Speed Condition	Running Speed	120% Design Overspeed
Critical Crack Size, a_{cr} (mm)	[ ]	[ ]
Number of Cycles for Failure, Nf	[ ]	[ ]

4.4 Failure Due to Stress Corrosion Cracking

An analysis was performed to determine the probability of a fully integral rotor bursting due to stress corrosion cracking. A crack is assumed to initiate at the rim where the stresses are highest, and propagate radically inward until it reaches the critical crack size for bursting. The probability of rotor fracture due to this failure mechanism is a function of the probability of crack initiation, the rate at which a crack could grow due to stress corrosion, and the critical crack depth that will lead to a burst at either the running speed or the design overspeed. Each of these factors is discussed below.

For this analysis, it is only necessary to consider [ ] on the rotor. During operation [ ] are surrounded with superheated steam. Experience has demonstrated that stress corrosion cracking does not occur in dry steam.

The probability of missile generation due to stress corrosion crack is obtained from the following equation:

$$P_{SCC} = q_i \cdot q_{cr} \cdot q_{OS} \tag{4.7}$$

where,

q_i is the probability of crack initiation

q_{cr} is the probability of flaw propagation until critical crack size on stress corrosion crack mode

q_{OS} is the probability that the unit will reach design over speed

For conservative evaluation of this probability, it is assumed that q_i, which is the probability of crack initiation, is 100%, even though we have not experienced finding cracks on fully integral nuclear low pressure rotors at inspection through 2009. Also, q_{OS} is assumed to be

100%, even though it is actually on the order of 10^{-5}, with proper maintenance of the turbine valve and control system. Therefore, the probability of missile generation due to stress corrosion crack is obtained conservatively by this analysis.

Furthermore, we have not experienced stress corrosion cracking on fully integral nuclear low pressure rotors, which are designed with relatively low yield stress materials, [ ] MPa, compared to center shaft built-up rotors, which have keyways. However, this probability analysis due to stress corrosion cracking is based on experimental high yield stress materials data, because it has the same composition, 3 1/2% Ni-Cr-Mo-V rotor steel.

4.4.1 Probability of Crack Initiation

The probability of crack initiation in disc i, q_i, is obtained from inspection records of nuclear turbines with built-up rotors, and is calculated for each disc number within each turbine style. This gives conservative estimates since the built-up rotors have stresses and yield strengths, which are significantly higher than those of fully integral rotors.

Suppose that N number i discs in a particular turbine style have been inspected and a total of K have been found with one or more cracks. We take:

[ ] (4.8)

for any number i disc in that particular turbine style.

We have not experienced to finding any cracks during the inspection of 22 existing rotors. However, for conservative estimation, the probability of crack initiation is assumed to be 100%.

4.4.2 Crack Growth Rates

The crack growth rate model used is as follows:

[ ] (4.9)

where,

[ ]

[ ]

[ ]

[ ]

The actual values used for the parameters on the crack growth rate model are the same as those used for keyway stress corrosion crack growth rate in built-up rotors. These values are:

[ ]

[ ]

[ ]

For [ ], a normal distribution with a mean value of [ ] is used. The distribution of [ ] is obtained from fatigue crack growth rate data presented in Table 4-4. The data includes different materials from the LP rotor of the South Texas Project unit 3 and 4, and can be regarded as having the larger deviation of term uncertainty than the data of the rotor material of the South Texas Project unit 3 and 4, 3 1/2% Ni-Cr-Mo-V. Using the larger deviation, the higher probability is calculated, therefore, the calculation results become more conservative.

The calculations were carried out for [ ] low pressure turbine discs using the maximum numerical average temperatures at the inlet faces of each disc.

Table 4-4 3 1/2% Ni-Cr-Mo-V Rotor Steel Deviation Crack Growth Rate from Calculation

Data No.	Growth Rate from Calculation $*10^{-4}$ mm/h	Growth Rate from Experiment $*10^{-4}$ mm/h	Logarithm Deviation
1	[ ]	[ ]	[ ]
2	[ ]	[ ]	[ ]
3	[ ]	[ ]	[ ]
4	[ ]	[ ]	[ ]
5	[ ]	[ ]	[ ]
6	[ ]	[ ]	[ ]
7	[ ]	[ ]	[ ]
8	[ ]	[ ]	[ ]
9	[ ]	[ ]	[ ]
10	[ ]	[ ]	[ ]
11	[ ]	[ ]	[ ]
12	[ ]	[ ]	[ ]
13	[ ]	[ ]	[ ]
14	[ ]	[ ]	[ ]
15	[ ]	[ ]	[ ]
16	[ ]	[ ]	[ ]
17	[ ]	[ ]	[ ]
18	[ ]	[ ]	[ ]

Data No.	Growth Rate from Calculation *10^{-4} mm/h	Growth Rate from Experiment *10^{-4} mm/h	Logarithm Deviation
19	[ ]	[ ]	[ ]
20	[ ]	[ ]	[ ]
21	[ ]	[ ]	[ ]
22	[ ]	[ ]	[ ]
23	[ ]	[ ]	[ ]
24	[ ]	[ ]	[ ]
25	[ ]	[ ]	[ ]
26	[ ]	[ ]	[ ]
27	[ ]	[ ]	[ ]
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37	[ ]	[ ]	[ ]
38	[ ]	[ ]	[ ]
39	[ ]	[ ]	[ ]
40	[ ]	[ ]	[ ]
41	[ ]	[ ]	[ ]
42	[ ]	[ ]	[ ]
43	[ ]	[ ]	[ ]
44	[ ]	[ ]	[ ]

4.4.3 Critical Crack Size

The critical crack depths were obtained for [ ] of fully integral rotors, with [ ] yield strength, by using the relationship between fracture toughness and stress intensity. Stress intensity factors were determined at running speed and 120% overspeed. In each case, the influence of thermal stress was included. The thermal stress used was that determined to be the most severe during a transient condition. At running speed, the stress intensity for all crack depths less than the total depth of the disc was well below the fracture toughness. Therefore, it is conservatively assumed that the total depth of the disc is the critical crack depth on running speed. A limit load analysis confirms that ductile fracture of the rotor would not occur under these conditions.

The depth of the disc is taken as the distance between the rim of the disc and the point where it blends into the main body of the rotor.

In determining critical crack size at overspeed, we use the relationship between fracture toughness and stress intensity. The relationship is obtained as follows:

$$K_{IC\_SCC} \geq K_I = \phi \cdot \sigma \sqrt{\pi \cdot a} \tag{4.10}$$

If the above equation can be satisfied, rotor burst will occur by stress corrosion crack growth. Thus, for conservatism, a larger stress, $\sigma' \equiv n \cdot \sigma$, stress at overspeed is utilized as is a smaller critical crack size, *a'*. Rotor burst is as follows:

$$a' = \frac{K_I^{\,2}}{\phi^2 \cdot \pi} \cdot \frac{1}{\sigma'^2} \equiv \frac{1}{n^2} \cdot a \tag{4.11}$$

The critical size at 120% over speed is:

$$a_{cr\_os} = \frac{1}{1.4^2} \cdot a_{cr} \tag{4.12}$$

<u>4.4.4 Numerical Results</u>

With the distributions of crack growth rates and critical crack sizes described in the previous sections, analyses were made to determine the probability that a crack would grow to the critical size within any time interval, *t*. To get the probability of a rotor bursting, this probability is modified by the number of discs being considered, the probability of crack initiation, and for the design overspeed conditions, the probability that the unit will reach design overspeed.

Since the probability that the unit will reach design over speed has been unknown, its probability is assumed to be 100% to evaluate the probability of missile generation conservatively.

The final probability values are given in terms of discrete inspection intervals in Table 4-5 and are shown graphically in Figure 4-1. The results show that the inspection interval needed to satisfy the requirement that the probability of missile generation be less than 10^{-5} per year is [ ] years or more, even with the conservative assumptions incorporated by this analysis.

Table 4-5 Probability of Rotor Rupture Due to Stress Corrosion

Inspection Interval (yrs)	Probability of Rotor Rupture at	
	Running Speed	120% Design Overspeed
12.0	[ ]	[ ]
16.0	[ ]	[ ]
20.0	[ ]	[ ]
24.0	[ ]	[ ]
28.0	[ ]	[ ]
32.0	[ ]	[ ]
36.0	[ ]	[ ]
40.0	[ ]	[ ]

[ ]

Figure 4-1 Probability of Rotor Rupture Due to Stress Corrosion

5. Discussion and Conclusions

Except for the destructive overspeed mechanism, this report demonstrates that the fully integral low pressure rotor design for the South Texas Project unit 3 and 4 is unlikely to generate a missile by any of the mechanisms considered. The probability of reaching destructive overspeed is primarily dependent upon the [ ]. [ ]

The low pressure rotors are not likely to burst as a result of a high-cycle fatigue mechanism since the maximum alternating stress is less than the endurance stress obtained from the Goodman diagram, and their safety factors are greater than 3.0. Additional assurances against bursting by this mechanism are derived from the following:

1. In fully integral rotors, the locations of maximum stress are readily accessible for inspection during normal maintenance.
2. Bursting by this mechanism is unlikely, since the existence of a large transverse crack is detectable by high vibrations due to rotor unbalance.

It is reasonable to eliminate high cycle fatigue as the controlling mechanism for determining in-service inspection intervals.

Analysis of the low cycle fatigue mechanism demonstrates that the number of cycles for failure by this scenario is extremely large, even when utilizing highly conservative assumptions. Periodic in-service inspections for low cycle fatigue cracks will not contribute significantly to improvement in safety. Therefore, low cycle fatigue is also eliminated as the controlling mechanism for determining inspection intervals.

As with previous designs, the potential for stress corrosion cracking has the greatest influence on rotor integrity. However, in fully integral designs, such as that used in the low pressure rotors of the South Texas Project unit 3 and 4, the probability of failure by this mechanism has been reduced. The analysis shows that [ ] years or more of running time, also utilizing highly conservative assumptions, may elapse before inspection, without exceeding the NRC safety criteria. Considering typical use factors for nuclear turbines, and considering that the crack locations are readily observable during normal turbine maintenance, it is concluded that periodic safety related inspections are not required within the expected life of the turbine.

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Technical Report

Probabilistic Evaluation of Turbine Valve Test Frequency

South Texas Project, Units 3&4

Koji Jibiki
Sept.28, 2010

Approved by
Turbine Control Device Design Group
Turbine Design & Assembling Dept.

Toshiba Corporation
KEIHIN PRODUCT OPERATION

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1. EXECUTIVE SUMMARY

The purpose of this report is to provide the detailed probabilistic basis for the valve test interval.
The annual probability of turbine missile ejection has been calculated using detailed nuclear turbine operating data from Japanese nuclear power stations which use Toshiba turbine generators. Testing of turbine valves affects the probability that the valves will be incapable of closing given that the load on the turbine is lost. The failure or unavailability of the turbine valve safety function affects or contributes to the probability that the turbine will overspeed and eject a missile.

Turbine missiles can be ejected at overspeeds that are less than the destructive or runaway speed of the turbine. The current study has attempted to quantify the total risk of turbine missile ejection at destructive (Approximately [ ] percent of rated turbine speed) and at lower overspeeds. The lower overspeeds were evaluated in two categories: design overspeed and intermediate overspeed. The total missile ejection risk is developed in this report as the sum of the missile ejection probabilities from each of the three overspeed categories. Section *5* of this report discusses the basis for the analysis of turbine overspeed.

Section 6 of this report contains the detailed results of the probabilistic investigation.

The evaluation showed that the probability of turbine missile generation with quarterly valve testing is less than the evaluation criteria.

2. INTRODUCTION

In recognition of the effects of turbine valve testing on the probability of low pressure turbine missile ejection, Toshiba Corporation evaluated the need for periodic valve testing and to establish appropriate test intervals. This report contains the results of that evaluation.

The evaluation performed consisted of estimation of component failure rate and the annual probability of missile ejection. Failures of turbine valves and overspeed protection components were evaluated on the basis of Japanese nuclear steam turbine operating experiences. The annual probability of missile ejection was calculated for various test intervals.

3. TURBINE VALVE TESTING AND IMPACT

Testing is conducted to verify that equipment is capable of performing its intended function. The turbine valves function to control and protect the main turbine. They must be capable of moving freely in response to control and protection signals. Valve testing ideally tests these abilities or detects non-performance of these abilities including the associated active components of the EHC system. There are two degrees of performance or non-performance that testing may potentially demonstrate:

1. Equipment failure - the complete non-performance of equipment function.

2. Equipment failure precursors - identification of equipment conditions that will eventually lead to failure if not corrected.

A test which only identifies equipment failure is useful in limiting the time after failure that the faulty equipment may be relied on. A test which identifies failure precursors can impact the time between and the number of failures if the precursors are acted on. This section of the report addresses turbine valve testing and its implications on valve failure rate.

3.1 TURBINE VALVE TESTING

Periodic testing of turbine valves consists of movement of each of the turbine valves. Typically, this test is conducted by the control room operator. Valve testing verifies freedom of movement of the valve stem and plug, the actuator rod and piston and verifies proper operation of either the servo valve, servo, or motor, depending on which valve is being tested, and the associated drain line (return line) to the reservoir. Testing verifies smooth movement and operability of the valves.

In addition to periodic testing, valve tests and inspections during a shutdown can detect distress or conditions that would lead to future valve failure. In the current study, the valve inspection interval was not an input parameter. However, actual service experience has been used in the calculation of valve failure rates (Section 6). It is believed that these failure rates reflect the normal practice with respect to inspection and maintenance of turbine valves.

3.2 SURROGATE VALVE TESTING

Periodic valve testing primarily demonstrates the ability of the valve to respond to a signal and close upon demand. Both planned and unplanned turbine trips can also demonstrate these abilities and can be considered as surrogate valve tests for which a valve test "credit" can be taken, since all turbine trips result in the dumping of emergency trip oil and the operation of systems which dump high pressure oil or hydraulic fluid from the turbine valve actuators.

For both planned and unplanned trips, if plant operators observe the valve operation with its position indicator during the trip and verify there has been no evidence of malfunction of control or valves, then this operator activity would be qualified as a surrogate valve test.

3.3 VALVE FAILURE MODES AND IMPACT OF TESTING

The dominant occurrence of valve failure modes, such as sticking and mechanical damage, can be attributed to the following:

1. Movement or loss of valve internal components including the quality of EHC fluid
2. Cracking or breaking of the valve seat
3. Piston seal ring-bonnet, bushing, or liner galling or distress
4. Misalignment of valve linkage

These conditions are primarily internal to the valves, and periodic testing would identify these conditions only to the extent that they are apparent to an operator or that they prevent valve operation. Periodic testing most often identifies failures. Failure precursors that do not noticeably affect the rate of closure or final position of a valve are not easily detected in testing. For example, a cracked valve seat could potentially result in later valve seat failure and subsequent internal valve binding; however, the "precursor" could not be detected during testing, only the subsequent failure of the valve could be detected. However, the valve testing is effective to increase reliability of the overspeed protection system.

4. DESCRIPTIONS OF TURBINE VALVES AND OVERSPEED CONTROLS

The following sections describe the turbine valves and its control system. The turbine valve arrangement for STP-34 is shown in Figure 5-1.

4.1 TURBINE VALVES

Main stop valves and control valves, and intercept and intermediate stop valves are located in the steam lines to the high and low pressure turbines, respectively.

Main stop valves close automatically in response to the dumping oil of emergency trip system (ETS) which will occur in an overspeed trip or a system separation. The controls and trips that dump emergency trip oil are discussed in Section 4.2. In normal operation, each main stop valve is held open against a closing spring force by high pressure oil acting on the servo-actuator piston. Each main stop valve has a disc dump valve that opens if the ETS pressure is dumped. This in turn, routes the high pressure oil to drain and the main stop valve, equipped with large closing springs, closes rapidly.

Control valves adjust the inflow of steam to the turbine in response to the speed or load demand placed on the turbine-generator. Each has a servo valve and a disc dump valve. The servo valve receives an electrical input from the electronic controller and positions the steam valve through the control of high pressure oil to the servo-actuator. The electronic controller is a digital processor receiving turbine speed and reactor dome pressure inputs. The control valve will move rapidly to the fully-closed position if the disc dump valve is opened by a trip or protective device that dumps the oil of relayed emergency trip system (RETS). Various controls and trips, discussed in Section 4.2, are designed to dump the oil of RETS on loss of load or overspeed.

Intercept and intermediate stop valves are held open by high pressure oil operating on the pistons of the servo-actuators. Each intercept valve has a disc dump valve that is connected to RETS oil header.

The disc dump valves will open in response to a dump of the emergency trip oil and close the intercept valves, Intermediate stop valves have disc dump valves that are connected to ETS oil header.

The intermediate stop valves will close in response to a dump of ETS oil.

4.2 TURBINE CONTROL AND OVERSPEED PROTECTION

The digital electrohydraulic control (D-EHC) control system controls the flow of steam to the turbine and permits the selection of the desired turbine speed and acceleration rates. The primary speed channel and reactor dome pressure are the primary inputs to the valve electronic controller, which positions the control valves. If the turbine accelerates from its normal speed, the normal speed control system and servo valve on each control valve will rapidly reduce the oil pressure acting on the control valve servo-actuators. This causes the control valves to close until the turbine returns to normal speed.

The following additional overspeed protection controls are provided to prevent overspeed.

First, the power-load unbalance (PLU) will activate after a loss of load if the load unbalance exceeds approximately 40%, and automatically energizes fast acting solenoid valves that will drain the emergency trip oil and cause the CVs and IVs to fast close.

Second, a primary overspeed trip system will trip the turbine at approximately 110% speed. The primary overspeed trip system has three separate speed pickups with independent circuits, separate power supplies, 2 out of 3 trip logic, and separate trip solenoid valve to drain emergency trip oil to cause MSVs, CVs, ISVs, and IVs to close.

Lastly, an emergency overspeed trip system is also provided. It uses separate speed sensors, separate power supplies, 2 out of 3 trip logic, and will trip its trip solenoid at approximately 111% speed, to drain emergency trip oil to cause MSVs, CVs, ISVs, and IVs to close. The emergency ovespeed trip system is diverse, separate, and independent from the primary trip system.

In the event of a turbine trip prior to a generator trip, the opening of generator output breakers is delayed following the turbine trip. Experience has shown that without being loaded by the generator, residual steam energy can cause turbines to overspeed. Immediately following a turbine trip, with the steam supply cut off, the turbine is allowed to motor with turbine speed governed by grid frequency. This allows remaining steam to be exhausted and steam lines depressurized prior to a generator trip (removal of load).

5. BASIS FOR ANALYSIS

5.1 TURBINE VALVE ARRANGEMENT AND CONTROL OIL SYSTEM

Figure 5-1 describes the turbine valves on the steam inflow lines to the high pressure turbine and the low pressure turbine.

The steam turbine for STP-34 plant in the study has the D-EHC system. Appendix A shows the applicable control oil system drawing.

The trip components were described in Section 4 of this report. The control oil system for STP-34 steam turbine has overspeed trip systems, which dump the emergency trip oil in a manner to close all the steam valves including MSV, CV, ISV and IV. The dump of emergency trip oil causes an emergency trip valve to open, which dumps the emergency trip oil for the MSVs & ISV and emergency trip oil for the CVs & IVs.

This system also includes relay trip valve which will dump the emergency trip oil for the CVs & IVs.

5.2 IDENTIFICATION OF OVERSPEED EVENTS

Before discussing the type of overspeed events that are of concern in this study, it should be pointed out that turbine overspeed is sometimes planned for the purpose of testing overspeed trip mechanisms. The test conditions can be controlled so that during trip testing the turbine speed is between rated speed and 110% speed of rated speed, trip set point. The risk of missile ejection at the overspeed trip set point (110&111 percent of rated speed) is small and was not evaluated in this study. The current study focuses on overspeed events that occur inadvertently following a system separation or loss of load. These events generally involve system failure sequences causing overspeeds that approach or exceed the design overspeed of the turbine.

"Design overspeed," "Intermediate overspeed" and "Destructive overspeed" were taken into consideration in this study.

The "Design overspeed" event is one in which the maximum speed of the turbine approaches but does not exceed an overspeed of 120 percent of rated speed. "Design overspeed" will be approached if the overspeed protection controller or the control valves or intercept valves fail to function and the main stop and intermediate stop valves close after turbine speed reaches the overspeed trip setpoint.

The following is a description of the basis for "Design overspeed":

1. System separation occurs

2. One or more control valves, or one or more intercept valves, fail to close immediately following loss of load

3. Successful overspeed trip: the main stop valves and intemediate stop valves close

"Intermediate overspeed" has been estimated to be approximately 10 percent above design overspeed. Generally, intermediate overspeed involves a failure to block to the low pressure turbine. The failure of the intermediate stop and intercept valves to close at the overspeed trip setpoint results in a transfer of energy to the low pressure turbine for a longer duration than what occurs in design overspeed.

The following is a description of the basis for "lntermediate overspeed" for the turbine:

1. System separation occurs

2. One or more alignments of ISV/IV remain open

"Destructive overspeed" results from failure of one or more main stop valves to close and failure of one or more control valves downstream of the failed main stop valve. Destructive overspeed is on the order of [ ] percent of rated speed. Failure of ISV or IV has no impact on this event. The following is an abbreviated description of the basis for "Destructive overspeed":

1. System separation occurs
2. One or more control valves fail to close
3. One or more main stop valves fail to close

5.3 BASIS FOR CALCULATION OF MISSILE, EJECTION PROBABILITIES

The regular testing of turbine valves and the regular inspection of the low pressure turbine rotors during normal maintenance are two effective ways of controlling and managing the risk of turbine missile ejection. The main goal of this sturdy was to determine the effect of turbine valve test interval on the probability of turbine missile ejection (which is discussed separately in Reference 2). Turbine valve testing affects only the probability of missile ejection resulting from overspeed of the turbine. Therefore, this study concentrated on missile ejection from overspeed.

Before discussing the basis for calculating the probability of missile ejection due to overspeed, it should be mentioned that all of the plants have a program of low pressure rotor inspection. In the deterministic program, the LP rotors are inspected during normal maintenance. The time that it takes for a hypothetical crack in the rotor to grow to critical size (the crack size that is just large enough to result in rotor failure with probability of 1.0E-05) is calculated. The inspection interval is established to be less than this probabilistic failure time.

The effect of varying the turbine valve test interval was evaluated by calculating the total probability of turbine missile ejection, P, for the three identified overspeed events. The formula used to calculate P is reproduced in Table 5-1 and is discussed in the following paragraphs.

The probability of missile ejection due to design overspeed is the product of the probability of design overspeed, P(A), and the conditional probability of missile ejection at design overspeed, P(M/A). In other words, P(M/A) is the probability of ejecting a missile given that the turbine reaches design overspeed. A product of P(B) and P(M/B) results in the probability of missile ejection for the intermediate overspeed event. P(C) by itself denotes the probability of missile ejection for the destructive overspeed event because the conditional probability, P(M/C), is assumed to be one in the study.

P(M/A) was obtained from probabilistic reports on missile ejection from fully integral low pressure turbine rotors (Reference 2). It involves a calculation of the probability of failure of low pressure turbine rotor based on TOSHIBA Corporation crack growth data, the stress generated at design overspeed, and the resultant critical crack size.

The probability of low pressure turbine rotor failure is broken into two parts: the probability that a crack initiates and the probability that the crack has grown beyond critical size after a certain interval of time.

Section 4 of Reference 2 shows the probability of missile ejection depending on safety related inspection intervals and concludes that the probability of missile ejection from fully integral rotor with low yield strength is extremely low when the rotor rotating speed is suppressed under "Design overspeed" or "Intermediate overspeed."

Based on the above discussion, it can be concluded that probability of P(A)＊P(M/A) and P(B)＊P(M/B) is negligibly small compared to P(C) in case of full integral rotor with low yield strength, which will be applied to STP-34 low pressure turbine rotor.

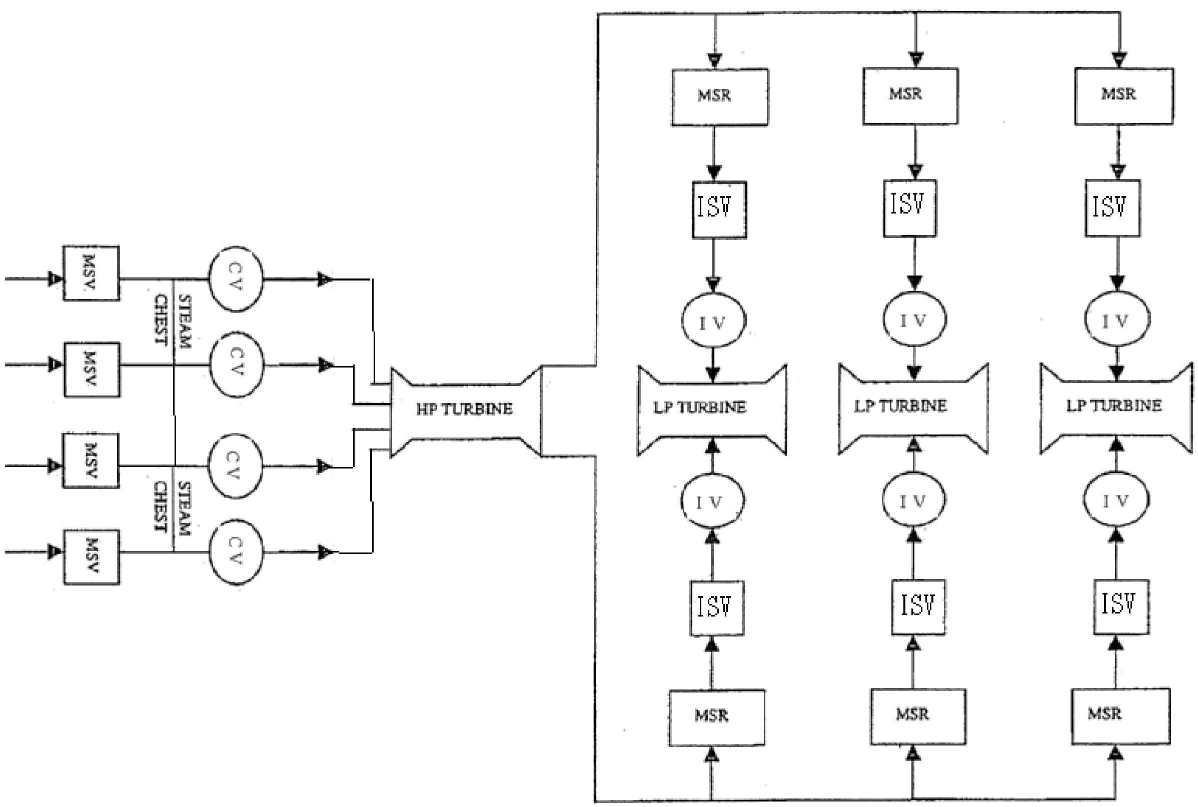
Section 6 of this report gives the detailed results of the evaluation of P for the various turbine valve test intervals.

5.4 ASSUMPTIONS (BASIS FOR ANALYSIS)

The assumptions below pertain to the basis for analysis:

- The design overspeed events are assumed to result in 120 percent overspeed even though it is likely that the actual overspeed would be less. This gives additional conservatism to the analysis.
- P(A)＊P(M/A) and P(B)＊P(M/B) is negligibly small compared to P(C) and these probability can be regarded as zero (0).
- P(C) is the annual probability of destructive overspeed results from failure of one or more main stop valves to close and failure of one or more control valves downstream of the failed main stop valve. Failure of ISV or IV is assumed to have no impact on this event.

Table 5-1 Basis for Calculation of P(Resulting From Turbine Overspeed)	
P=P(A)*P(M/A)+P(B)*P(M/B)+P(C)	
Where:	
P	Annual probability of turbine missile ejection
P(A)	Annual probability of design overspeed
P(B)	Annual probability of intermediate overspeed
P(C)	Annual probability of destructive overspeed
P(M/A)	Conditional probability of missile ejection at design overspeed
P(M/B)	Conditional probability of missile ejection at intermediate overspeed



Legend

MSV : Main Stop Valve
CV : Control Valve
ISV : Intermediate Stop Valve
IV : Intercept Valve
MSR : Moisture Separation Reheater

Figure 5-1 Arrangement of Turbine Valves

6. FAILURE DATA AND ANALYSIS OF BASIC FAILURE PROBABILITY

6.1 SOURCES OF FAILURE DATA AND METHOD OF ANALYSIS

The primary source of basic failure data in this study was from the operating experience of TOSHIBA Corporation nuclear steam turbines. A total of 10 nuclear units data was used for this study.

The basic service experience data and years of service, is given in Table 6-1 and Table 6-2.

6.2 DETERMINATION OF FAILURE RATE OF EACH COMPONENT

Failure rates of each component including main stop valve (MSV), MSV control system, control valve (CV) and CV control system were obtained based on the following equation and calculated results with *95%* confidence are shown in Table 6-3.

Failure Rate	:	$\lambda(\alpha)/2$
$\lambda(\alpha)$	:	$\chi^2(\phi, 1-\alpha)/T$
χ^2	:	Chi square distribution
T	:	Accumulated operating hours
ϕ	:	Degree of freedom=2f+2
f	:	Number of observed failure

6.3 DETERMINATION OF ANNUAL PROBABILITY OF TURBINE MISSILE EJECTION

According to the discussion in Section *5* in this study, probability of turbine missile ejection for STP-34 was determined by the following equations.

Table 6-5 demonstrates the calculated results showing the relationship between annual probability of turbine missile ejection and time interval of valve tests.

System Separation Rate, Qss, is evaluated based on 10 Japanese BWR nuclear plant experiences. Tables 6-1 and 6-2 show the number of system separations that occurred during turbine on-load conditions and the accumulated operating hours of the 10 BWR units. These data lead to the conclusion that the probability of system separation during operation is [ ]. In order to make the evaluation conservative, ten (10) times the probability of system separation above, is [ ], is adopted in this evaluation.

$$P = N*4*(Qsv + Qsc)*(Qcv + Qcc)* Qss$$

P	:	Probability of turbine missile ejection	1/Time Interval
Q_{SV}	:	Failure Probability of MSV = $q_{SV}/2n$	1/Time Interval
Q_{SC}	:	Failure Probability of MSV control system = $q_{SC}/2n$	1/Time Interval
Q_{CV}	:	Failure Probability of CV = $q_{CV}/2n$	1/Time Interval
Q_{CC}	:	Failure Probability of CV control system = $q_{CC}/2n$	1/Time Interval
Qss	:	System Separation Probability	1/Time Interval

N	:	Number of main steam pipes	—
n	:	Number of valve tests per month	—
q_{SV}	:	Failure rate of MSV	per month
q_{SC}	:	Failure rate of MSV control system	per month
q_{CV}	:	Failure rate of CV	per month
q_{CC}	:	Failure rate of CV control system	per month

Where, "Time Interval" denotes "Time Interval between Valve Tests"

Table 6-1 Basic Service Experience Data in Japanese Nuclear Power Stations

Unit Name		MSV Fault	CV Fault	MSV Control System Fault	CV Control System Fault	System Separation
1	ONAGAWA NO.1					
2	ONAGAWA NO.2					
3	HIGASHIDORI NO.1					
4	#1FUKUSHIMA NO.3					
5	#1FUKUSHIMA NO.5					
6	#2FUKUSHIMA NO.1					
7	#2FUKUSHIMA NO.3					
8	KASHIWAZAKI NO.1					
9	KASHIWAZAKI NO.2					
10	KASHIWAZAKI NO.3					
TOTAL (As of 3/31/2009)						

Table 6-2 Years of Service for Unit and Component in Japanese Nuclear Power Stations

Unit Name	Output (MW)	Accumulated Operating Hours of Unit (Note 1,2) (hr)	Number of MSV (-)	Number of CV (-)	MSV Component Accumulated Operating Hours (hr)	CV Component Accumulated Operating Hours (hr)
ONAGAWA NO.1						
ONAGAWA NO.2						
HIGASHIDORI NO.1						
#1FUKUSHIMA NO.3						
#1FUKUSHIMA NO.5						
#2FUKUSHIMA NO.1						
#2FUKUSHIMA NO.3						
KASHIWAZAKI NO.1						
KASHIWAZAKI NO.2						
KASHIWAZAKI NO.3						
TOTAL						

Note-1 : Accumulated Operating Hours of Unit includes trial operation hours

Note-2 : Accumulated Operating Hours of Unit as of 2009.3.31

Table 6-3 Failure Rate of Each Components (95% Confidence)				
Component	**T: Accumulated Operating Hours (hr)**	**f: Number of Failures (-)**	**Failure Rate**	
			Mean (-/hr)	**Upper Limit (95% Confidence) {-/hr}**
MSV				
MSV Control System				
CV				
CV Control System				
System Separation				

Note : Failure Rate derived based on following equations
Failure Rate (Mean) = f (Number of Failure)/T (Accumulated Operating Hours)
Failure Rate (Upper Limit) = $\lambda(\alpha)/2$

Table 6-4 Upper Limit Failure Rates						
	Unit	MSV	MSV Control System	CV	CV Control System	System Separation
F: Number of Failure						
ϕ : Degree of Freedom = 2f+2						
$\chi^2(\phi,1-\alpha)$						
T: Accumulated Operating Hours						
$\lambda(\alpha)=\chi^2(\phi,1-\alpha)/T$						
Failure Rate (Upper Limit) = $\lambda(\alpha)/2$						

Table 6-5 Annual Probability of Turbine Missile Ejection (95% Confidence)						
Time Interval Between Turbine Valve Tests = 1 (Month)						
		Unit	MSV	MSV Control	CV	CV Control
Failure Rate (Upper Limit)	q	per Hour				
		per Month				
Frequency of Valve Test	n	per Month				
Time Interval of Valve Test		Month				
Probability of Failure	Q=q/2n	1/(Time Interval)				
	$(Q_{SV}+Q_{SC})$ or $(Q_{CV}+Q_{CC})$	1/(Time interval)				
Probability of System Separation	Q_{SS}	per hour				
		1/(Time Interval)				
Probability of Turbine Missile	P	1/(Time Interval)				
		per Year				
Time Interval Between Turbine Valve Tests = 2 (Month)						
		Unit	MSV	MSV Control	CV	CV Control
Failure Rate (Upper Limit)	q	per Hour				
		per Month				
Frequency of Valve Test	n	per Month				
Time Interval of Valve Test		Month				
Probability of Failure	Q=q/2n	1/(Time Interval)				
	$(Q_{SV}+Q_{SC})$ or $(Q_{CV}+Q_{CC})$	1/(Time Interval)				
Probability of System Separation	Q_{SS}	per hour				
		1/(Time Interval)				
Probability of Turbine Missile	P	1/(Time Interval)				
		per Year				
Time Interval Between Turbine Valve Tests = 3 (Month)						
		Unit	MSV	MSV Control	CV	CV Control
Failure Rate (tipper Limit)	q	per Hour				
		per Month				
Frequency of Valve Test	n	per Month				
Time Interval of Valve Test		Month				
Probability of Failure	Q=q/2n	1/(Time Interval)				
	$(Q_{SV}+Q_{SC})$ or $(Q_{CV}+Q_{CC})$	1/(Time Interval)				
Probability of System Separation	Q_{SS}	per hour				
		1/(Time Interval)				
Probability of Turbine Missile	P	1/(Time Interval)				
		per Year				

Table 6-5 Annual Probability of Turbine Missile Ejection (95% Confidence) (cont.)						
Time Interval Between Turbine Valve Tests =6 (Month)						
		Unit	MSV	MSV Control	CV	CV Control
Failure Rate (Upper Limit)	q	per Hour				
		per Month				
Frequency of Valve Test	n	per Month				
Time Interval of Valve Test		Month				
Probability of Failure	Q=q/2n	1/(Time Interval)				
	(Q_{SV}+Q_{SC}) or (Q_{CV}+Q_{CC})	1/(Time Interval)				
Probability of System Separation	Qss	per hour				
		1/(Time Interval)				
Probability of Turbine Missile	P	1/(Time Interval)				
		per Year				
Time Interval Between Turbine Valve Tests = 12 (Month)						
		Unit	MSV	MSV Control	CV	CV Control
Failure Rate (Upper Limit)	q	per Hour				
		per Month				
Frequency of Valve Test	n	per Month				
Time Interval of Valve Test		Month				
Probability of Failure	Q=q/2n	1/(Time Interval)				
	(Q_{SV}+Q_{SC}) or (Q_{CV}+Q_{CC})	1/(Time Interval)				
Probability of System Separation	Qss	per hour				
		1/(Time Interval)				
Probability of Turbine Missile	P	1/(Time Interval)				
		per Year				

Figure 6-1 Annual Probability of Turbine Missile Ejection (95% Confidence)

7. CONCLUSION

Turbine valve testing is performed at an interval that achieves a turbine missile probability rate P of 1.0E-05 or less per year. From Table 6-5 above, the resulting turbine missile probability rate is [ ] per year with a 3 month valve test interval. This value is below the evaluation criteria of 1.0E-05 or less per year.

Therefore it can be shown that a 3 month valve testing interval can be implemented and meet the evaluation criteria of <1.0E-05 per year*.

* This acceptance criteria is the same as the value of P1 which comes from NUREG-0800, SRP 3.5.1.3, Table 3.5.1.3-1 for an unfavorably oriented turbine. It represents the general, minimum reliability requirement for loading the turbine and bringing the system on line.

References

1. H. L. Ornstein, "Operating Experience Feedback Report - Turbine - Generator Overspeed Protection Systems Commercial Power Reactors", U.S. Nuclear Regulatory Commission, NUREG-1275 Vol. 11, 1995.

2. [Tominaga, J., "Analysis of the Probability of the Generation of Missiles from Fully Integral Nuclear Low Pressure Turbines", UTLR-0008-P, 2010]

APPENDIX A

CONTROL OIL DIAGRAMS

AND

OVERVIEW OF THE TURBINE OVERSPEED CONTROL SYSTEM

Affidavit for Withholding Confidential and Proprietary Information from Public Disclosure under 10 CFR § 2.390

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of

STP Nuclear Operating Company — Docket Nos.52-012, 52-013

South Texas Project
Units 3 and 4

AFFIDAVIT

I, Takashi Suzuki, being duly sworn, hereby depose and state that I am Chief Specialist, Turbine Design & Assembling Department, Keihin Product Operations, Power Systems Company, TOSHIBA CORPORATION, that I am duly authorized by TOSHIBA CORPORATION to sign and file with the Nuclear Regulatory Commission the following application for withholding TOSHIBA CORPORATION's confidential and proprietary information from public disclosure; that I am familiar with the content thereof; and that the matters set forth therein are true and correct to the best of my knowledge and belief.

In accordance with 10 CFR § 2.390(b)(ii), I hereby state, depose, and apply as follows on behalf of TOSHIBA CORPORATION:

(A) TOSHIBA CORPORATION seeks to withhold from public disclosure the documents listed in Attachment 1 of this affidavit, and all information identified as "Toshiba Proprietary Information" therein (collectively, "Confidential Information").

(B) The Confidential Information is owned by TOSHIBA CORPORATION. In my position as Chief Specialist, Turbine Design & Assembling Department, Keihin Product Operations, Power Systems Company, TOSHIBA CORPORATION, I have been specifically delegated the function of reviewing the Confidential Information and have been authorized to apply for its withholding on behalf of TOSHIBA CORPORATION.

(C) The reports listed in Attachment 1 provide technical justification of overspeed protection philosophy for the turbine manufactured by TOSHIBA CORPORATION. Specifically, the justification includes both missile generation probability from Low Pressure Turbine and Test frequency of associated steam shut off valves based on TOSHIBA CORPORATION's operating experience. The Confidential Information which is entirely confidential and proprietary to TOSHIBA CORPORATION is indicated in the document using brackets.

(D) Consistent with the provisions of 10 CFR § 2.390(a)(4), the basis for proposing that the Confidential Information be withheld is that it constitutes TOSHIBA CORPORATION's trade secrets and confidential and proprietary commercial information.

(E) Public disclosure of the Confidential Information is likely to cause substantial harm to TOSHIBA CORPORATION's competitive position and its business relations with the turbine-pump vendor by (1) disclosing confidential and proprietary information about the methodology or database for evaluating reliability of nuclear steam turbine and associated components to other parties whose commercial benefit may be adverse to those of TOSHIBA CORPORATION, and (2) giving such parties access to and use of such information at little or no cost, in contrast to the significant costs incurred by TOSHIBA CORPORATION to develop such information.

TOSHIBA CORPORATION has a rational basis for determining the types of information customarily held in confidence by it, and utilizes a system to determine when and whether to hold certain types of information in confidence.

The basis for claiming the information so designated as proprietary is as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of TOSHIBA CORPORATION's competitors without license from TOSHIBA CORPORATION constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of TOSHIBA CORPORATION, its customers or suppliers.

(e) It reveals aspects of past, present, or future TOSHIBA CORPORATION or customer funded development plans and programs of potential commercial value to TOSHIBA CORPORATION.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the TOSHIBA CORPORATION system which include the following:

(a) The use of such information by TOSHIBA CORPORATION gives TOSHIBA CORPORATION a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the TOSHIBA CORPORATION competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the TOSHIBA CORPORATION ability to sell products and services involving the use of the information.

(c) Use by our competitor would put TOSHIBA CORPORATION at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving TOSHIBA CORPORATION of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of TOSHIBA CORPORATION in the world market, and thereby give a market advantage to the competition of those countries.

(f) The TOSHIBA CORPORATION capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

Further, on behalf of TOSHIBA CORPORATION, I affirm that:

(i) The Confidential Information is confidential and proprietary information of TOSHIBA CORPORATION.

(ii) The Confidential Information is information of a type customarily held in confidence by TOSHIBA CORPORATION, and there is a rational basis for doing so given the sensitive and valuable nature of the Confidential Information as discussed above in paragraphs (D) and (E).

(iii) The Confidential Information is being transmitted to the NRC in confidence.

(iv) The Confidential Information is not available in public sources.

(v) Public disclosure of the Confidential Document is likely to cause substantial harm to the competitive position of TOSHIBA CORPORATION, taking into account the value of the Confidential Information to TOSHIBA CORPORATION, the amount of money and effort expended by TOSHIBA CORPORATION in developing the

Confidential Information, and the ease or difficulty with which the Confidential Information could be properly acquired or duplicated by others.

T. Suzuki

Sep. 28, 2010

Takashi Suzuki
Chief Specialist
Turbine Design & Assembling Department
Keihin Product Operations
Power Systems Company
TOSHIBA CORPORATION

Attachment 1 to the Toshiba Affidavit to the NRC

(Proprietary Information)

DOCUMENTS ENCLOSED (TO BE WITHELD FROM PUBLIC DISCLOSURE PER 2.390)

Item	Document Description	Document Number	Rev
1.	Analysis of the Probability of the Generation of Missiles from Fully Integral Nuclear Low Pressure Turbines (Proprietary Version)	UTLR-0008-P	1
2.	Probabilistic Evaluation of Turbine Valve Test Frequency (Proprietary Version)	UTLR-0009-P	1

認　　　証

嘱託人株式会社東芝主幹鈴木孝史は、公証人の面前で、添付書面に署名した。

よって、これを認証する。

平成２２年　9 月　28　日、本公証人役場において

横浜市中区羽衣町2丁目7番10号

横浜地方法務局所属

公　証　人

Notary

KENJI　TERANISHI

証　　　明

上記署名は、横浜地方法務局所属公証人の署名に相違ないものであり、かつ、その押印は、真実のものであることを証明する。

平成２２年　9 月　28　日

横浜地方法務局長　　椿　栄一

APOSTILLE

(Convention de La Haye du 5 octobre 1961)

1. Country : JAPAN
This public document
2. has been signed by KENJI TERANISHI
3. acting in the capacity of Notary of the Yokohama District Legal Affairs Bureau
4. bears the seal/stamp of KENJI TERANISHI , Notary

Certified

5. at Tokyo　　　6. SEP. 2 8. 2010
7. by the Ministry of Foreign Affairs
8. 10- №　300549
9. Seal/stamp :　　　10.Signature :

MINISTRY OF FOREIGN AFFAIRS JAPAN

Kazutoyo OYABE

For the Minister for Foreign Affairs

Registered No. 125 of 2010.

Certificate of Acknowledgment of Notary

On this 28th day of September, 2010, before me, KENJI TERANISHI, a notary in and for YOKOHAMA District Legal Affairs Bureau, personally appeared TAKASHI SUZUKI, Chief Specialist of TOSHIBA CORPORATION, with satisfactory evidence of his identification, affixed his signature to the attached document.

Witness, I set my hand and seal.

Notary

Notary's official seal

Kenji Teranishi

KENJI TERANISHI

Kannai-odori Notary office

2-7-10, Hagoromo-cho, Naka-ku, Yokohama-city, Japan.

Attached to the Yokohama District Legal Affairs Bureau.