ALSTOM

UNISTAR PROJECT

TURBINE MISSILE ANALYSIS

1 Summary

This report describes ALSTOM Power's method for the determination of the turbine missile generation probability P(T) for LP (Low Pressure) and HIP (High Intermediate Pressure) rotors in nuclear power plants.
The dominant mechanism is assumed to be stress corrosion cracking (SCC).
The probability of a rotor failure due to SCC consists of the probability of crack initiation and the probability of crack growth up to the critical crack size.
The analysis carried out for the UNISTAR preliminary design of the LP and HIP rotors, shows a very favorable low probability of missile generation. The main reasons are:

- ALSTOM Power have not experienced any cracks in any rotor of welded construction in the relevant radial-axial plane where they might have the potential to develop and release a missile
- Use of rotor material with a high resistance to SCC initiation and growth
- Low stresses at the locations where SCC cracks could initiate.

For the LP and HIP rotors, the cumulative probability of missile generation over the time has been computed considering the "worst" material properties in the acceptance band (i.e. highest $Rp_{0.2}$(68°F) = 102 ksi for LP rotors and 107 ksi for HIP rotor) and the unfavorably orientation of plant layout (i.e. the NCR value of $1.E^{-5}$ has to be considered as minimum limit for missile generation probability). It resulted that the maximum inspection interval that corresponds to the NRC specified probability, is 18.1 years for the LP rotors and 21.3 years for the HIP rotor. Considering instead, the recommended rotor inspection interval equal to 10 years of operation, the cumulative missile generation probability is $1.0E^{-6}$ and $0.9E^{-7}$ respectively for the LP and HIP rotors.

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First issue			I	Modifications	Date	Author	Approved
	Author	Approved	A	AREVA's comments taken into account	27-07-07	ROGE	GRUAU
Date	30-05-07	30-05-07	B	AREVA's comments n° V0063 taken into account	28-09-07	ROGE	GRUAU
Name	GRUAU	LAMARQUE	C	AREVA's comments n° V0064 taken into account	09-11-07	ROGE	GRUAU
Visa			D	Update of the exhaust	05-12-07	ROGE	GRUAU

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3 Summary of requirements of the U.S. Nuclear Regulatory Commission (NRC)

3.1 Introduction

The primary safety objective of the NRC is the prevention of unacceptable doses to the public from the releases of radioactive contaminants that could be caused by damage to plant safety-related structures, systems and components resulting from missile-generating turbine failures.

3.2 Criteria that must be met to Demonstrate Compliance with Regulations

According to General Design Criterion 4 of Appendix A to 10 Code of Federal Regulations Part 50, nuclear power plant structures, systems and components important to safety shall be appropriately protected against dynamic effects, including the effects of missiles.
Failures of the large steam turbines of the main turbine generator have the potential for ejecting large high-energy missiles that can damage plant structures, systems and components. The overall safety objective is to ensure that structures, systems and components important to safety are adequately protected from potential turbine missiles.
The probability of unacceptable damage resulting from turbine missiles (P4) is expressed as the product of:

- P1: the probability of turbine failure resulting in the ejection of turbine rotor (or internal structure) fragments through the turbine casing;
- P2: the probability of ejected missiles perforating intervening barriers and striking safety related structures, systems or components;
- P3: the probability of struck structures, systems or components failing to perform their safety function.

According to NRC guidelines stated in Section 3.5.1.3 of the Standard Review Plan (NUREG-0800), and Regulatory Guide 1.115, the probability of unacceptable damage from turbine missiles should be less than or equal to about 1 chance in 10 million per year for an individual turbine unit, that is :
$P4 = P1 \times P2 \times P3 \leq 10^{-7}$ per unit per year.

3.3 Procedure for Demonstrating Compliance with Regulations

The present approach places on the applicant the responsibility for demonstrating and maintaining NRC-specified turbine reliability by appropriate in-service inspection and testing throughout plant life. The applicant show capability to have volumetric (ultrasonic) examinations performed which are suitable for in-service inspection of turbine disks and shaft and to provide reports for NRC review and approval which describe his methods for determining turbine missile generation probabilities.
Because of the uncertainties involved in calculating P2, the NRC concluded that P2 analyses are "Ball Park" or "order of magnitude" only. On the basis of simple estimates for a variety of plant layouts, the staff further concluded that the strike and damage probability product can be reasonably taken to fall in a characteristic narrow range which is dependent on the gross features of turbine generator orientation.

- For favorably oriented turbine generators, P2 x P3 tend to lie in the range 10^{-4} to 10^{-3}.
- For unfavorably oriented turbine generators, P2 x P3 tend to lie in the range 10^{-3} to 10^{-2}.

For these reasons (and because of inadequate data, controversial assumptions and modeling difficulties) in the evaluation of P4, the NRC gives credit for the product of the strike and damage probabilities (P2 x P3) of 10^{-3} for a favorably oriented plant layout and 10^{-2} for an unfavorably oriented plant layout and does not encourage calculations of them.
The NRC safety objective with regard to turbine missiles is expressed in terms of two sets of criteria applied to the missile generation probability (P1), see Table 1.
One set of criteria is to be applied to favorably oriented turbines, and the other is to be applied to unfavorably oriented turbines.
Turbine manufacturers have to prepare reports describing their methods and procedures for calculating turbine missile generation probabilities (P1) for review and acceptance by the NRC.
Following the submittal of such reports to the NRC for review and approval, the manufacturer will provide applicants and licensees with tables of missile generation probabilities versus time (in-service volumetric disk inspection interval for design speed failure and in-service valve testing interval for destructive over speed failure) for their particular turbines, which are then to be used to establish inspection and test schedules which meet NRC safety objectives.

This report considers possible failure modes at rated speed and at design overspeed. It has to be pointed out that the probability of failure at gross overspeed (and thus at destructive overspeed) is largely dictated by the probability of reaching gross overspeed, which is function of the governing and protection system. This is dealt within Chapter 4 of the present document.

	Probability [per unit year]		Recommended licensee action
Case	Favorably oriented turbine	Unfavorably oriented turbine	
A	$P1<10^{-4}$	$P1<10^{-5}$	This is the general, minimum reliability requirement for loading the turbine and bringing the system on line.
B	$10^{-4}<P1<10^{-3}$	$10^{-5}<P1<10^{-4}$	If this condition is reached during operation, the turbine may be kept in service until the next schedule outage, at which time the licensee must take action to reduce P1 to meet the appropriate A criterion before returning the turbine to service.
C	$10^{-3}<P1<10^{-2}$	$10^{-4}<P1<10^{-3}$	If this condition is reached during operation, the turbine is to be isolated from the steam supply within 60 days, at which time the licensee is to take action to reduce P1 to meet the appropriate A criterion before returning the turbine to service.
D	$10^{-2}<P1$	$10^{-3}<P1$	If this condition is reached at any time during operation, the turbine must be isolated from the steam supply within 6 days, at which time the licensee must take action to reduce P1 to meet the appropriate A criterion before returning the turbine to service.

Table 1 : Turbine System Reliability Criteria

4 Governing and overspeed protection systems

4.1 Description of the governing and overspeed protection systems

The probability of reaching destructive overspeed, i.e. the probability of releasing a missile, is largely dictated by the probability to have a failure of the governing and overspeed protection system. Thus, the shaft-line overspeed risk is the most important event taken into account in the turbine governing and protection strategy.
Following topics are safety oriented to match a probability of reaching an overspeed higher than 120% of the rated speed, better than $5x10^{-5}$ per year :

- Valve design :
  - Two independent valves in series on each steam inlet.
  - Steam inlet valve designed in order to reduce the efforts and avoid jamming risk.
  - Fail safe hydraulic actuators closing by mechanical spring.
  - Valve full stroke tests performed monthly.
- Speed governor design :
  - Speed governor reliability based on a duty stand-by controller and 3 speed sensors.
  - Speed governor is acting on the governing valves.
  - Speed sensor supervision.
  - Speed limiter at 107 %, within governing system.
  - Acceleration limiter and power unbalance function, within governing system.
- Protection system design :
  - Independent protection system, failsafe, acting on all the steam inlet valves.
  - Triple redundant overspeed protection with SIL3 certification according to IEC61508 standard.
  - First and second overspeed protections made with different technologies.
  - Protection system action and tripping capability test, performed daily, in an automatic way.

- Reverse power relay :
  - Reverse power relay used to keep the circuit breaker closed, as long as the mechanical power is not cancelled.

4.2 Recommended periodic tests in relation with governing system and overspeed protection

4.2.1 Overspeed protection system

The probability to have a failure of the governing and overspeed protection system is linked to the in-service inspections and exercising intervals.
The recommended inspection and exercising of turbine valves and protection system are :

- At each refueling, (does not require any dismantling) :
  - HP stop valve tightness tested.
  - Valve and servomotor assembly behavior checked : travel time, stroke and travel effort.
  - Hydraulic protection circuit functional tested.
- During each refueling, one of the valves is inspected :
  - Visual and surface examinations (seats, stems and internal part of the HP valves, bearings and sealings of the IP valves).
- On load tests :
  - Overspeed system and Hydraulic trip block tested daily (in an automatic way).
  - Valves full stroke test : monthly for each valve (it is recommended that this test will be preceded by a limitation at 97% load in order to anticipate this load reduction associated with one valve closing).
  - Extraction non-return valve : power closing assistance checked.

4.2.2 Rotor couplings

Since a rupture of the couplings between the turbine rotors participates in the probability of reaching destructive overspeed, the coupling bodies and coupling bolts are inspected during each full maintenance overhaul, i.e. about every 10 years.

5 Description of ALSTOM Power welded rotors

5.1 Welded Rotor Design

The rotor design used by ALSTOM Power for large LP (Low Pressure) and HIP (High Intermediate Pressure) rotors is the welded type : 9 welds for the LP rotor and 3 welds for the HIP rotor (HP in one forged part and IP in 3 forged parts). Figure 1 shows a cross section of a LP rotor. Figure 2 shows a cross section of a HIP rotor.

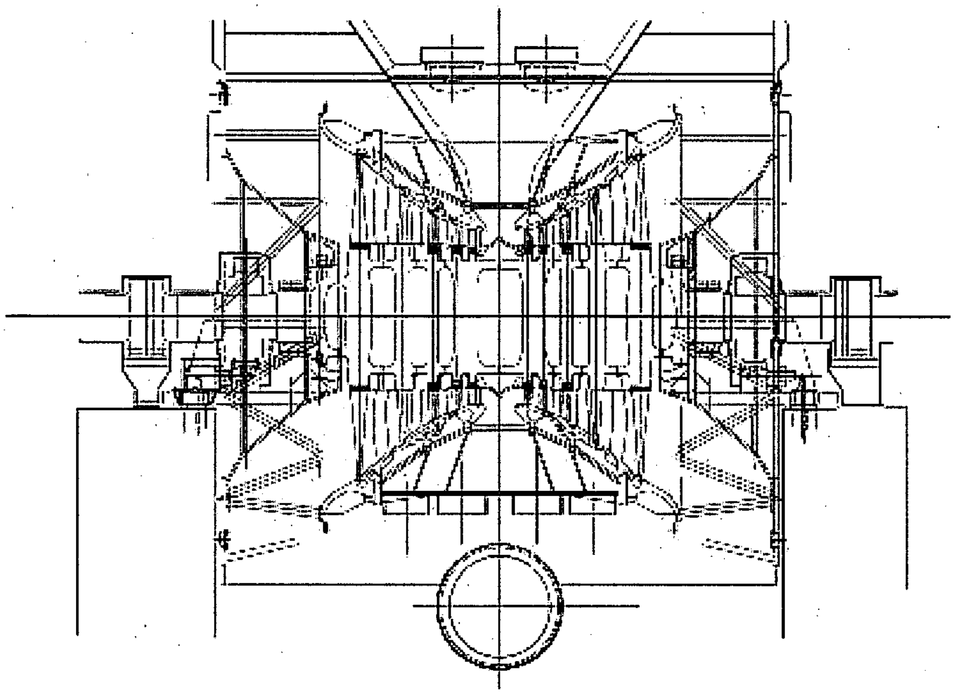


Figure 1 : Cross section of the welded LP rotor for UNISTAR

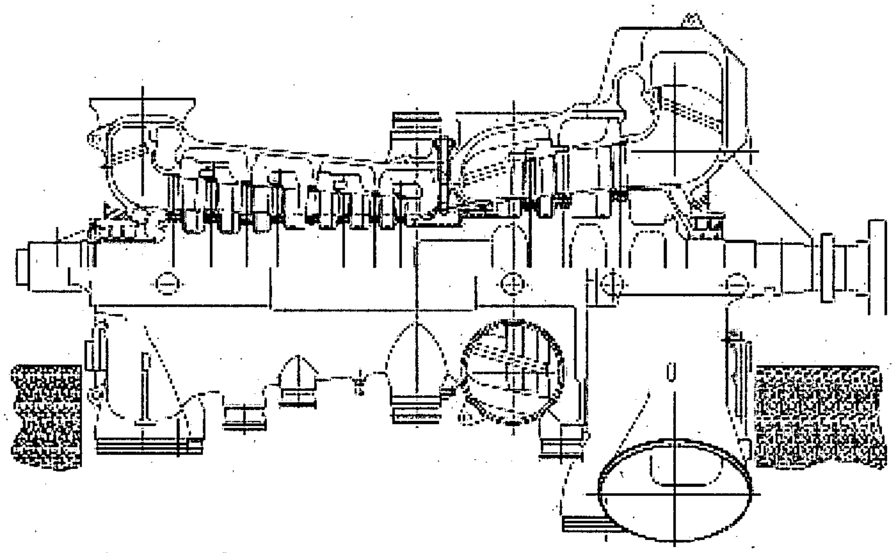


Figure 2 : Cross section of the welded HIP rotor for UNISTAR

A rotor consists of separate relatively small forgings welded together to form the complete rotor. The welds are positioned at the circumference and are of submerged arc type.
The main design features with respect to the turbine missile generation probability of the welded rotor are :

- Low stress levels which allows the use of low yield strength material with high stress corrosion resistance.
- No shrink fits, no key-ways and no central bore.
- The small forgings used are easy to forge and achieve homogenous material properties throughout the rotor.
- The small forgings used permit high resolution during ultrasonic inspection to be achieved.
- The welding procedure provides an inert gas atmosphere inside the cavities and around the center of the discs, where the net stresses are highest during operation. The cavities are closed after the welding procedure to prevent any steam exposure.

5.2 Description of Rotor Materials

The materials employed for the UNISTAR LP and HIP rotors are low alloy NiCrMo steels, in accordance with the following ALSTOM Power material delivery instructions :

- LP rotors : SBV MF1009 - ALSTOM Power designation B65AS – see Appendix 1 of this document
- HIP rotor : SBV MF1023 - ALSTOM Power designation STM528 - see Appendix 2 of this document

The grade of STM528 is similar to ASTM 471-05 class 2 vacuum treated alloy steel for forgings of turbine rotor discs and wheels. The steel B65AS is equivalent to the other ALSTOM Power steel designed St565S, and is differing mainly from STM528 by lower Ni content. These steels were developed for good weldability and were introduced in welded rotor design in 1967 for B65AS and 1986 for STM528S.
Table 2 summarizes the mechanical properties of the LP and HIP rotor materials.
It must be pointed out here that, research by ALSTOM Power clearly shows that the yield strength of the material is one of the key factors in SCC initiation and growth. The higher the yield strength, the lower the resistance to SCC initiation and the higher the growth rate.

Material data	B65AS	STM528
Ultimate tensile strength Rm(20 °C) Ultimate tensile strength Rm(68 °F)	Min 735 MPa Min 107 ksi	Min 720 MPa Min 104 ksi
Yield strength Re(20 °C) Yield strength Re(68 °F)	635-735 MPa 92-107 ksi	600-700 MPa 87-102 ksi

Table 2 : Rotor materials properties

The absorbed impact energy at room temperature is specified to be higher than 81J (see Appendix 1 and 2). The fracture appearance transition temperature FATT50 and the fracture toughness (KIC) are determined as indicated in Appendix 3. Hence the minimum possible fracture toughness KIc at 20°C (68°F) equals KIC(B&L) at FATT5, i.e. 160 ksi√in for the LP rotors and 155 ksi√in for the HIP rotor.

5.3 Description of Temperature and Stress Distribution in UNISTAR LP-Rotor

[Proprietary]

5.4 Description of Stress Distribution in UNISTAR HIP-Rotor

[Proprietary]

6 Operating experience with welded LP rotors in nuclear power plants

The first turbine generator in a nuclear power plant with welded LP rotors went into service in 1965. At the end of 2004 there were 277 ALSTOM Power welded LP rotors in operation in nuclear power plants. To date there have been no reports of rotor failures and no indications of stress corrosion cracking in the relevant radial-axial plane where they could extend to release a missile. The average operating hours of welded LP rotors, which have been in service for more than 3 years, is greater than 90'000 hours.

7 Hypothetical failure modes of welded LP rotors

As described in 6 there have been no failures of ALSTOM Power welded LP rotors in nuclear power plants up to now. Therefore the discussion of failure modes is purely hypothetical.
Based on the experience of stress corrosion cracking (SCC) in LP rotors of the shrunk on disc design, failures due to this type of cracking will be discussed as well as failures due to brittle fracture.

7.1 Failure Modes due to Stress Corrosion Cracking

7.1.1 Stress corrosion crack growth rate

Stress corrosion cracking in LP rotors is most likely to occur in the early wet stages, i.e. the region just after the Wilson-Line. As a conservative assumption, it is assumed that a stress corrosion crack can initiate not only in this area but also in every HP stages.
The propagation rate of stress corrosion cracks in steam turbine rotor steels depends on the applied stress intensity. An example for a similar material is illustrated in Figure 3.

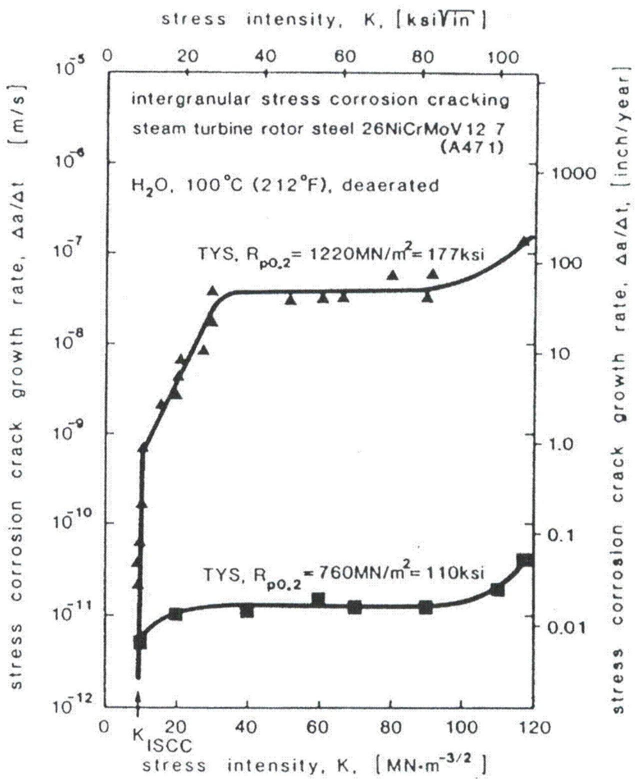


Figure 3 : Effect of stress intensity and yield strength on crack growth rate

At very low stress intensities, close to the threshold stress intensity KISCC, cracks grow slowly i.e. slower than 10^{-11} m/sec. As the stress intensity increases from KISCC the stress corrosion crack growth rate increases until a plateau is reached where the crack growth rate no longer depends on the stress intensity over a wide range of stress intensity. This "plateau" crack growth rate depends on various influences, for example on the yield strength of the steel. At higher stress intensities, a further acceleration of stress corrosion cracks growth is observed, but this is not well documented. Available stress corrosion crack growth data indicates that the plateau range extends to at least KI = 100 ksi√in. With respect to possible failure modes, this means that once a crack is initiated it will grow in a stable manner until the crack size reaches a value corresponding to at least 100 ksi√in.

7.1.2 Disc failure mode

In the case of a welded rotor, a crack with the potential to release missiles must develop in an axial-radial plane. The maximum principal stress, which is the crack driving stress, is the circumferential stress (see Figure 4).

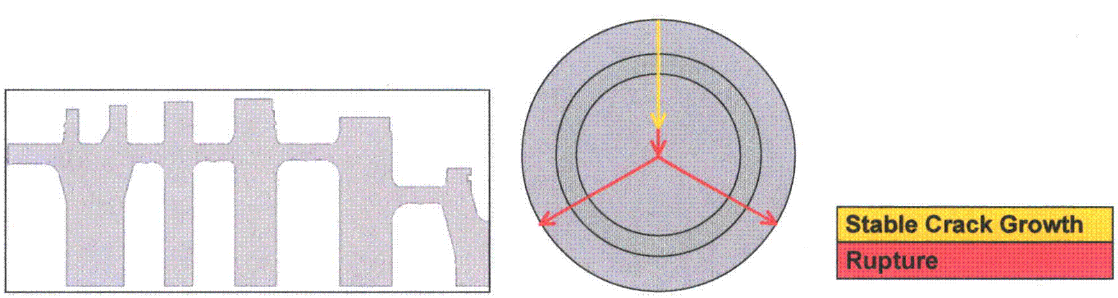


Figure 4 : Hypothetical failure mode of welded LP-rotor due to SCC

[Proprietary]

7.1.3 Cracks without potential to release missile outside the casings

[Proprietary]

7.1.4 Cracks with potential to release missile outside the casings

[Proprietary]

7.2 Failure Modes due to Brittle Fracture

A failure as a result of a brittle fracture in a LP or HIP rotor may occur during a cold start or an unforeseen over speed. The prerequisite of such an event is an existing flaw or crack inside the rotor reaching the critical crack size during operation.

ALSTOM Power assures by stringent requirements on the conditions of forgings for welded rotors that the discs do not have pre-existing flaws or inclusions of unacceptable size (see Delivery Instruction ETL-EP-MAT 07-005 in Appendix 4).

As mentioned in 5.2, the fracture toughness of the LP and HIP rotor materials are at least respectively 160 ksi√in and 155 ksi√in at a temperature of 20°C. According to NRC requirements, the ratio between fracture toughness and the maximum circumferential stress at design over speed (120% of the normal operating speed) shall exceed the value 2√in. The maximum stress in the LP rotor amounts to :

[Proprietary]

From these facts it can be concluded that a failure due to cyclic loading and brittle fracture is much more unlikely than a failure due to SCC.

8 ALSTOM Power method for calculating turbine missile generation probability (P1)

The missile generation probability of a turbine (P1) consists of two factors:

- P1' : the probability of rotor failure producing an internal turbine missile.
- P1" : the probability that this internal missile penetrates the casings and is ejected from the turbine.

Summarizing : P1 = P1' x P1"

The probability P1' can be determined by means of fracture mechanics, considering as probabilistic quantities the variables involved in the evaluation such as critical crack sizes, crack growth rates, stresses and temperatures. These properties and details are well documented in the case of turbine rotors.

The procedures for estimating P1" are not as sophisticated as the procedures for calculating P1'. The usual method is to compare the kinetic energy of a potential internal turbine missile with the energy necessary to perforate the turbine casing. The result of such an estimation will be either P1" = 0 or P1" = 1.0.

ALSTOM Power conservatively assumes P1" to be equal to one (1.0). This means the turbine missile generation probability equals the internal turbine missile generation probability : P1 = P1' (for both LP and HIP modules).

8.1 Method for Calculating Turbine Missile Generation Probability (P1) due to SCC

According to the present knowledge on SCC phenomena, three ranges have to be distinguished:

(1) Crack Initiation or Incubation Phase : it is commonly accepted that a threshold value KISCC exists. If the stress intensity KI is below this threshold, SCC is not expected.

(2) Constant Crack Growth Rate : if the stress intensity KI exceeds the threshold value KISCC the crack growth rate remains constant on a certain plateau-value for quite a large range of KI.

(3) Accelerated Crack Growth Rate, Critical Crack Size: if KI exceeds a certain amount, the assumption of a constant plateau-value is no longer valid. Available data indicate that the plateau range extends to at least 100 ksi√in, see also Figure 3.

It should be pointed out that this value is lower than the minimum specified fracture toughness of the UNISTAR LP and HIP rotor forgings (KIC =155 ksi√in), see 5.2).

In order to obtain results lying on the safe side, ALSTOM Power uses the plateau limit value KIP = 100 ksi√in for the determination of the critical crack sizes, i.e. the calculation is stopped when the crack growth reaches the end of the plateau.

As a conservative assumption, it will be considered that an SCC crack could appear in any blade pin-root attachment operating in wet steam, i.e. discs 2 and 3 of LP rotor and all the HP discs of the HIP rotor.

The probability of generating a missile (P1) under the conservative assumption P1 = P1', which was explained previously, is computed as a function of time as follows:

$$P_1(T) = \sum_{i=1}^{N} p_i(T) \cdot q_i \quad \text{valid for } p_i \cdot q_i \ll 1 \qquad \text{Eq 1}$$

Where :

N Number of discs in the unit, susceptible to SCC initiation
T Time in operating years
pi(T) Probability of missile generation in an individual disc.
qi Probability of crack initiation in an individual disc.

Due to the fact that the ALSTOM LP rotors in a unit have the same design and any crack will initiate at the same location, Eq 1 can be rewritten as :

$$P_1(T) = N \cdot p(T) \cdot q \qquad \text{Eq 2}$$

where N
N = Number of LP flows in the case of the LP discs
N = 1 in the case of the HP discs

8.1.1 Probability of Crack Initiation, q

[Proprietary]

8.1.2 Probability of Missile Generation of an Individual disc, p (T)

[Proprietary]

8.1.2.1 Critical Crack Size, ac

The critical crack size ac for a semi-elliptical surface crack is given by:

$$a_c = G \cdot \frac{1}{1.21 \cdot \pi} \cdot \left[\frac{K_{IC}}{\sigma}\right]^2 \qquad [\text{ in }] \qquad \text{Eq 3}$$

Where:
G Flaw geometry factor
KIC Fracture toughness
σ Operational net stress at nominal speed.

Generally G, KIC and σ are uniformly distributed variables. With respect to this, the following assumptions are made :

8.1.2.2 Flaw Geometry Factor G

G is a uniformly distributed variable ranging from 1.0 to 1.5. Hence, the mean is G = 1.25 and the standard deviation is SG = 0.144.

8.1.2.3 Fracture Toughness KIC

The plateau values of the constant crack growth rate are only established properly to an upper limit of stress intensity KIP = 100 ksi√in. The available test results are not sufficient to perform a statistical analysis with respect to the scattering of this plateau limit.
Laboratory tests performed by ALSTOM Power indicate that the assumed limit KIP = 100 ksi√in is a reasonable conservative value. Furthermore, it is considerably lower than the minimum fracture toughness of the UNISTAR LP and HIP rotors (respectively 160 ksi√in and 155 ksi√in).
For these reasons, the conservative value of KIP = 100 ksi√in is taken as a constant and not a random variable.

8.1.2.4 Operational Net Stress

[Proprietary]

The influence of design over speed is not taken into consideration, because these events are very few and have a short duration, so that the effect on crack propagation from SCC can be neglected.
Due to the fact that all stresses and temperatures are calculated by the Finite Element Method, a relative standard deviation $S\sigma/\sigma = \pm 5$ % is realistic, and σ is assumed to be normal distributed.

8.1.2.5 [Proprietary]

[Proprietary]

8.1.2.6 Distribution of Sac

The distribution of ac is calculated by means of Equation 8 and according to the distribution of its parameters G and σ.

8.1.3 Computer Code

The procedure described above was computerized by ALSTOM Power.
The program calculates the probability for an individual LP flow p(T), and generates a plot showing the total probability P1(T) according to Eq 3 for a given turbine generator versus operating years.

8.1.4 Overspeed

The critical crack size was determined with the nominal operating stress and a fracture toughness of KIC = KIP = 100 ksi√in.
The risk of rotor fracture at design over speed is incorporated within the risk of fracture at normal speed. This is the result of considerable conservatism in the assessment of risk of fracture at normal speed. As discussed in 7.1, it is well established that the rate of stress corrosion crack growth is insensitive to the crack stress intensity and hence, under constant stress, is insensitive to crack size. But this only applies up to a certain level of stress intensity, beyond which crack growth accelerates. It is a convenient simplification to assume that crack growth at normal rotor speed continues at a uniform rate until it reaches the point of acceleration, at a stress intensity of 100 ksi√in, where after it is very conservatively assumed to progress at such a rapid rate as to lead almost immediately to fracture.
It follows that only cracks growing at normal rotor speed to stress intensities lower than 100 ksi√in could be the cause of fracture at overspeed.
For a design overspeed of e.g. 120% of normal speed, the crack stress intensity of 100 ksi√in at normal speed rises to 1.20^2x100 ksi√in = 144 ksi√in, which is lower than the lowest specified fracture toughness UNISTAR LP and HIP rotor forgings (respectively 160 ksi√in and 155 ksi√in). Therefore any crack that might possibly lead to fracture at design over speed has already been conservatively assumed to cause fracture at normal speed, and must not be counted a second time in the evaluation of fracture probability.
In case the LP rotor will reach burst speed (i.e. > 150%), it will burst irrespective of whether cracks have previously developed within it. Thus the probability of missile release at burst speed is equal to the probability of the burst speed occurring. Burst speed, owing to failure of the control & protection system and leading to rotor bursting has not been computed.

8.2 Determination of Inspection Intervals

The maximum allowable inspection intervals are determined by evaluating the results for the turbine missile generation probability P1(T) for the individual turbine generator.

According to the NRC requirements given in 3.3, the limit for P1(T) will be either 10^{-4} for favorably oriented plants or 10^{-5} for unfavorably oriented plants. For UNISTAR the unfavorably oriented plant will be considered and therefore a limit of 10^{-5} applies.

In the inspection and overhaul plans, ALSTOM Power recommends major rotor inspection intervals of 10 years for plants that are maintained in accordance with the typical recommended procedures provided in Figure 5 (note that this procedure has to be adapted to the refueling schedule for UNISTAR).

Aim of the analysis is to demonstrate that the risk of missile generation due to stress corrosion cracking is completely covered by the usual inspection programs and no additional measures have to be introduced to meet the NRC missile probability limit.

Maintenance Type	C	P	R	P	R	P	D	P	P	R	P	R	P	D
HP-IP module	X			X1			X				X1			X
LP1 module	X				X2			X				X2		
LP2 module			X2			X				X2			X	
LP3 module		X2		X					X2		X			
Maintenance Type	P	P	R	P	R	P	D	P	P	R	P	R	P	D
HP-IP module				X1			X				X1			X
LP1 module	X				X2			X				X2		
LP2 module			X2			X				X2			X	
LP3 module		X2		X					X2		X			
Maintenance Type	P	P	R	P	R	P	D	P	P	R	P	R	P	
HP-IP module				X1			X				X1			
LP1 module	X				X2			X				X2		
LP2 module			X2			X				X2			X	
LP3 module		X2		X					X2		X			

In general	X	Full maintenance overhaul
HP-IP module	X1	Partial maintenance overhaul
LP module	X2	Partial maintenance overhaul to check last blades and rubber O rings

C	First Contractual Overhaul
P	Partial Overhaul
R	Maintenance during Refueling
D	10 years Global Maintenance

Figure 5 : Recommendations for inspection intervals of large turbine generators

8.3 Recommended Rotor Inspection

[Proprietary]

The recommended inspection requirements for LP rotors during major overhauls ensures that any indications of SCC will be detected. The inspection includes a thorough visual inspection for erosion and corrosion and magnetic particle examination at selected areas to detect any cracking at the rotor surfaces. In the very unlikely event of surface indications being detected, additional ultrasonic examinations will be performed.

A complete volumetric ultrasonic inspection for SCC is not necessary in the case of welded rotors.

9 Results for UNISTAR Rotors

9.1 Program Input for LP rotor

9.1.1 Critical Crack Size ac

[Proprietary]

9.1.2 Crack Growth Rate r

[Proprietary]

9.1.3 Crack Initiation q and number of Individual Flows N

[Proprietary]

9.2 Program Input for the HIP rotor

9.2.1 Critical Crack Size ac

[Proprietary]

9.2.2 Crack Growth Rate r

Mean value r (see 8.1.2.1 **Erreur ! Source du renvoi introuvable.**)
Sr = 0.587 (see 8.1.2.1).
Tc (see 8.1.2.1) : the mean temperature in the discs was considered to compute the crack growth rate.

9.2.3 Material Proof Strength

A worst case Missile Analysis was carried out for UNISTAR HIP rotors, which is based on the maximum proof strength specified for the material forgings where SCC could occur (i.e. $Rp_{0.2}$(68°F)=700 MPa, 102 ksi).

9.2.4 Crack Initiation q and number of Individual Flows N

[Proprietary]

9.3 UNISTAR Input Variables, Program Output and Inspection intervals for LP rotor

The input variables for the worst case which is the discs 3 of the LP rotors of UNISTAR are summarized in Table 3.

[Proprietary]

Table 3 : Input data for the Missile Analysis Program

As a result of the computation, the cumulative probability (P1) is plotted versus service life (years) for the disc 3LP and for N = 6. As UNISTAR LP rotors could be unfavorably oriented, 1e-5 figure has to be taken as minimum limit (see 3.3, Table 1).

[Proprietary]

Figure 6 : LP rotor of UNISTAR : Probability P1(T) vs. time (years), 3LP discs

With the same process as for the 3LP, the cumulative probability (P1) is plotted versus service life (years) for the disc 2LP and for N = 6. Furthermore, the sum of P1(T) for 2LP and 3LP is plotted.

[Proprietary]

Figure 7 : LP rotor of UNISTAR : Probability P1(T) vs. time (years), 2 & 3LP discs

As shown in Figure 7, 18.1 years is the maximum inspection interval for UNISTAR LP rotors that corresponds to the NRC specified probability of 10^{-5}. The maximum inspection interval associated with a probability of 10^{-4} is 32.8 years. When considering 10 years of operation instead of probability of 10^{-4} or 10^{-5} , the cumulative missile generation probability is $1.0E^{-6}$.

9.4 UNISTAR - Program Output and Inspection intervals for HIP rotor

As a result of the computation, the cumulative probability (P1) is plotted versus service life (years) for all the individual HP discs from 1HP to 8HP. Furthermore, the sum of P1(T) for 1HP to 8HP is plotted. As UNISTAR HIP rotors could be unfavorably oriented, 10^{-5} figure has to be taken as minimum limit (see 3.3, Table 1).

[Proprietary]

Figure 8 : HIP rotor of UNISTAR : Probability P1(T) vs. time (years), 1 to 8HP discs

As shown in Figure 8, 21.3 years is the maximum inspection interval for UNISTAR HIP rotors that corresponds to the NRC specified probability of 10^{-5}. The maximum inspection interval associated with a probability of 10^{-4} is 34.5 years. When considering 10 years of operation instead of probability of 10^{-4} or 10^{-5} , the cumulative missile generation probability is $0.9E^{-7}$.

10 List of Appendix

Appendix 1	**ETL-EP-MAT 07-003 : Rotor forgings in B65A-S for nuclear steam turbine**
Appendix 2	**ETL-EP-MAT 07-004 : Rotor forgings in STM528 for nuclear steam turbine**
Appendix 3	**HZLM 620206 : Test Instructions - Determination of KIc acc. to Begley and Logsdon**
Appendix 4	**ETL-EP-MAT 07-005 : Inspection for internal defects - Ultrasonic examination**

Rotor forgings in B65A-S for nuclear steam turbine

1. Scope

The present instruction applies to forged pieces for turbine rotors made of B65A-S. This instruction summarizes the requirements concerning mechanical properties of rotor forgings specified in the delivery instruction SBV MF1009.
If the value in the delivery instruction SBV M1009 deviates from the values indicated in the present instruction, the requirements of the latter will apply.

2. Tests

The following requirements, as stated in the delivery instruction SBV MF1009, must be verified:

2.1 Tensile properties at room temperature

Each welded rotor consists of several shaft parts (forgings). The requested yield and tensile strength values are specified hereafter :

		MPa	(ksi)
Rm	Ultimate tensile strength	≥ 735	(≥ 106,6)
Re	Yield strength or 0,2% proof strength	635 - 735	(92 – 106,6)

2.2 Notched – bar impact test at room temperature (minimum operating temperature)

	J	(ftlb)
AKV (ISO-V)	≥ 81	(≥ 60)

2.3 Toughness determination

2.3.1 FATT 50

The FATT 50 value shall be determined according to ASTM A 370. The determined FATT 50 shall not be higher than –18°C (0°F).

2.3.2 Fracture toughness at room temperature

This examination has only to be performed if requested in the I&T plan. The K_{1C} value shall be estimated from tangential oriented tensile and Charpy – V specimens from the outer test ring using the Begley and Logsdon method (according to instruction HZLM 620206). The estimated K_{1C} value is for information only.

2.4 Other requirements

For the other requirements the material delivery instruction SBV MF1009 shall apply. The tests shall be carried out according to the instructions SBV MF2002 and SBV MF2004.

3. Documentation

The requested test values 2.1 to 2.3.2 must be stated in the test certificate.

4. Reference documents

SBV MF1009	Material specification B 65 A-S steel
SBV MF2002	Product general technical specification low-alloy stell forgings for components of welded rotors for steam turbines
SBV MF2004	Particular technical specification of part – Low-alloy steel forgings for components of welded rotors for steam turbines
HZLM 620206	Determination of KIC cc. to Begley and Logsdon

Rotor forgings in STM 528 for nuclear steam turbine

1. Scope

The present instruction applies to forged pieces for turbine rotors made of STM 528. This instruction summarizes the requirements concerning mechanical properties of rotor forgings specified in the delivery instruction SBV MF1023.
If the value in the delivery instruction SBV M1023 deviates from the values indicated in the present instruction, the requirements of the latter will apply.

2. Tests

The following requirements, as stated in the delivery instruction SBV MF1023, must be verified:

2.1 Tensile properties at room temperature

Each welded rotor consists of several shaft parts (forgings). The requested yield and tensile strength values obtained after post-welding heat treatment are specified hereafter:

		MPa	(ksi)
Rm	Ultimate tensile strength	≥ 720	(≥ 104,2)
Re	Yield strength or 0,2% proof strength	600 - 700	(87 – 101,5)

2.2 Notched – impact test at room temperature (minimum operating temperature)

The following values shall be verified after post-welding heat treatment:

		J	(ftlb)
AKV (ISO-V)	transversal	≥ 81	(≥ 60)

2.3 Toughness determination

2.3.1 FATT 50

The FATT 50 value shall be determined according to ASTM A 370. The determined FATT 50 shall not be higher than –30°C (-22°F).

2.3.2 Fracture toughness at room temperature

This examination has only to be performed if requested in the I&T plan. The K_{1C} value shall be estimated from tangential oriented tensile and Charpy – V specimens from the outer test ring using the Begley and Logsdon method (according to instruction HZLM 620206). The estimated K_{1C} value is for information only.

2.4 Other requirements

For the other requirements the material delivery instruction SBV MF1023 shall apply. The tests shall be carried out according to the instructions SBV MF2004, SBV MF2002, SBV MF2001 and SBV MF2005.

3. Documentation

The requested test values 2.1 to 2.3.2 must be stated in the test certificate.

4. Reference documents

SBV MF1023	Material specification STM 528 steel
SBV MF2002	Product general technical specification low-alloy stell forgings for components of welded rotors for steam turbines
SBV MF2004	Particular technical specification of part – Low-alloy steel forgings for components of welded rotors for steam turbines
SBV MF2001	Product general technical specification low-alloy steel forgings for monobloc rotors for steam turbines
SBV MF2005	Particular technical specification of part – Low-alloy steel forgings for steam turbine welded rotors service temperature below 300°C
HZLM 620206	Determination of KIC cc. to Begley and Logsdon

ABB	ABB Kraftwerke AG			HZLM 620206	
Responsible department: KWTD	Take over department:	Revision: B 99-02	Doc.-type: PA	File no.: PG 103E-15-015	
Prepared: 99-02-01 Nachbaur	Checked: 99-02-03 Ebner	Approved: 99-02-08 Harasgama		Language: en	Page: 1/3
Valid for:	Derived from:	Replaces same No.	Classify no.	Data set: PG 103E	

Test Instructions

Determination of K_{IC} cc. to Begley and Logsdon

Text:	PA-KIC-Determination	Document no.:	HZLM 620206

Dept.	Document No.	Type	Rev.	Released	Lng.	Status
9610	HZLM620206	CJ	B	2002-03-13	EN	Approved

1 Scope

These instructions specify the procedure and evaluation of the measurements for determining K_{IC} acc. to Begley and Logsdon; they apply when this method is explicitly required in the technical instructions, the test plan or the order.

2 Purpose and Application

The method acc. to Begley and Logsdon is used to evaluate the fracture mechanics of forgings.
It has been proved that the real K_{IC} curves (ASTM E 399-81) as a function of temperature can be estimated on the basis of tensile and impact tests.

3 Procedure

3.1 Fundamentals of the Method

Begley and Logsdon compared numerous K_{IC} values in function of temperature with empiric formulas and found out that the K_{IC} value corresponding to FATT 95 (95% brittle fracture, i.e. in the low shelf of the energy absorbed temperature curve) is proportional to the 0,2% yield strength ($R_{p0,2}$) at FATT 95 temperature:

$$K_{IC} = 0{,}0717\ R_{p0,2}$$

(K_{IC} given in Mpa $\sqrt{m}$ if $R_{p0,2}$ in MPa) (1)

The value at FATT 95 is taken for the 0,2% yield strength ($R_{p0,2}$).

The value K_{IC} for a temperature FATT 5 (5% brittle fracture, i. e. in the high shelf of the energy absorbed temperature curve) is obtained by the equation

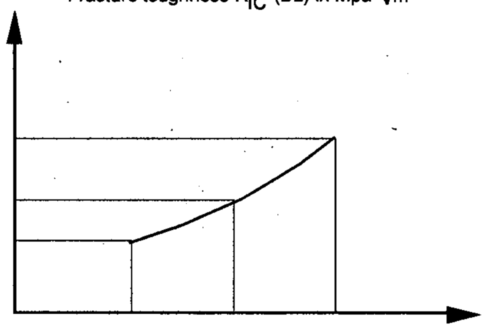
$$K_{IC} = R_{p0,2} \bullet \left(\frac{0{,}645}{R_{p0,2}} \bullet A_v - 0{,}00635 \right)^{1/2} \quad (2)$$

(K_{IC} in Mpa $\sqrt{m}$, $R_{p0,2}$ in Mpa, A_v in J)

The values at FATT 5 are taken for the 0,2% yield strength ($R_{p0,2}$) and the enegy absorbed (A_v).

The mean value of the values established for FATT 5 and FATT 95 is K_{IC} at FATT 50.

The development of K_{IC} as a function of material temperature can be estimated by drawing a curve through the three points FATT 5 / 50 / 95; see figure.



The letters "BL"must be added to distinguish between fracture toughness values calculated acc. to Begley and Logsdon and values determined by fracture mechanics tests.

Dept. 9610 | Document No. HZLM620206 | Type CJ | Rev. B | Released 2002-03-13 | Lng. EN | Status Approved

3.2 Measurements

3.2.1 Specimens

Normal ISO-V specimens (EN 10045-1) or Charpy-V specimens (ASTM E 23) are used for the notched bar impact tests and round, short proportional bars (EN 10002-1 and ASTM E8) for the tensile tests.

3.2.2 Notched Bar Impact Test

The brittle fracture surface-temperature curve from 0% to 100% brittle fracture is obtained by making three tests at each of the seven adequately chosen temperatures (the first three tests are usually carried out at room temperature).

The test temperatures should be such that the values to be determined are obtained by interpolation and not extrapolation. Hence follows:

FATT 5 (temperature at 5% brittle fracture, in the high shelf)
FATT 50 (temperature at 50% brittle fracture, in the transition zone)
FATT 95 (temperature at 95% brittle fracture, in the low shelf)

The energy absorbed-temperature curve shows

A_{v5} (energy absorbed at FATT 5 temperature)
A_{v50} (energy absorbed at FATT 50 temperature)
A_{v95} (energy absorbed at FATT 95 temperature)

The arithmetic mean value of the three tests made at one temperature is the value of the energy absorbed.

3.2.3 Tensile Tests

The tensile tests with extensometer are carried out to determine the 0,2% yield strength at FATT 5 and FATT 95 temperature.

3.3 Evaluation for K_{IC} (BL)

a) acc. to equation (1), the fracture toughness at FATT 95 is calculated using the value $R_{p0,2}$ (at FATT 95).

b) acc. to equation (2), the fracture toughness at FATT 5 is calculated using the values $R_{p0,2}$ (at FATT 5) and A_v (at FATT 5).

c) the fracture toughness at FATT 50 is determined as the mean values of a) and b).

d) in accordance with 3.1, the curve

$$K_{IC}\ (BL) = f\ (T)$$

is obtained by drawing a curve through the three values.

4. Test Certificate

The certificate must specify the following particulars:

- Position of the tensile- and notched bar impact test specimens in the test piece or drawing number
- Results of the notched bar impact tests as
  - a) brittle fracture surface-temperature curve showing all 21 values
  - b) energy absorbed-temperature curve showing all 21 measured values
- Energy absorbed A_{v5}, A_{v50}, A_{v95} (J) and temperatures FATT 5, FATT 50, FATT 95 (°C)
- Result of the tensile tests at FATT 5 and FATT 95

$$(R_{p0,2}, R_m, Z, A_5)$$

- Fracture toughness-temperature curve including FATT 5 and FATT 95 with the calculated values K_{IC} (BL) at FATT 5 / 50 / 95 in Mpa $\sqrt{m}$.

Dept. 9610 | Document No. HZLM620206 | Type CJ | Rev. B | Released 2002-03-13 | Lng. EN | Status Approved

Inspection for internal defects – Ultrasonic examination

1 Scope and time of examination

The ultrasonic examination shall take place at the following stages:

a) Before the quality heat treatment

b) After the quality heat treatment at a stage of the final machining such that it should allow another quality heat treatment when the measured permeability is inadequate.

This inspection shall allow to specify which defects are acceptable before the quality heat treatment and verify that such defects have not evolved in the course of the heat treatment.

The inspection shall be carried out in conformance with IBA R22405. The entire volume of the part shall be examined with longitudinal waves.

The extent of the inspection for stage (a) is as follows:

- For forgings, used for HP part of HIP rotors:
  - Specified in Attachment 6 to this document

- For forgings, use for IP part of HIP rotors or for LP rotors:
  - Discs: item 1 of attachment 1 to this document
  - Shaft ends without integral disc: item 1 and 2 of attachment 2 to this document
  - Shaft ends with integral disc: item 1 and 2 of attachment 3 to this document
  - Rings: item 1 of attachment 4 to this document

For stage (b) the extent of inspection is as follows:

- For forgings, use for HP part of HIP rotors:
  - Only the inspection corresponding to item 1 in attachment 6 to this document shall be performed. Any defective region (containing one or more indications exceeding the reporting limits) detected during stage a) examinations shall undergo a further examination to check the evolution of indications.

- For forgings, use for IP part of HIP rotors or for LP rotors:
  - Discs: All of attachment 1 to this document
  - Shaft ends without integral disc: All of attachment 2 to this document
  - Shaft ends with integral disc: All of attachment 3 to this document
  - Rings: All of attachment 4 to this document

Note: at stage (a) the supplier may supplement this inspection with order probing if he deems it necessary.

2 Evaluation of indications

The indications shall be characterized in accordance with IBA R22405.

3 Reporting threshold and criteria

3.1 Reporting thresohold

The following shall be reported:

- Any area showing a reduction in the back echo amplitude exceeding 6 dB,
- Any indication of relecting capacity greater than or equal to the reporting threshold for the maximum severity class corresponding to the area in which the indication is located.

The acceptance classes are given in table N°1.

For forgings used for HP part of HIP rotors, the diagrams showing maximum severity acceptance classes by area are given in attachment N°7 to this document.
For forgings used for IP part of HIP rotors or for LP rotors, the diagrams showing maximum severity acceptance classes by area are given in attachment N°5 to this document.

Note: - For examination at stage:

a) corresponding to probing in axial direction of item 1 of attachment 3 to this document, the probing sensitivity must enable detection of a defect with an equivalent diameter of 1,6 mm at a depth equal to the disc thickness.

b) corresponding to item 3 of attachment 2 to this document and items 1 and 3 of attachment 3 to this document, the probing sensitivity must enable detection of a defect with an equivalent diameter of 1,6 mm at a depth equal to the maximum radius of the part.

3.2 Criteria

The following shall be unacceptable:

- Any reduction in back echo amplitude exceeding 6 dB
- Any linear indication
- Any indication exceeding the acceptance criteria for the class of the area in which the indication is located.

The acceptance classes are given in Table N°1.

The diagrams showing the maximum severity acceptance classes are given in attachment N°5 to this document.

If one or more indications exceeding the acceptance criteria for the maximum severity class of the area considered are detected, interpretation of the defect map shall be subjected to a detailed examination by the forging shop, the manufacturer and the main contractor.

4 Reference documents

SBV MF 2004	Particular technical specification of part – Low-alloy steel forgings for components of welded rotors for steam turbines
SBV MF2005	Particular technical specification of part – Low-alloy steel forgings for steam turbine welded rotors service temperature below 300°C
IBA R22405	Inspection methods - Ultrasonic examination of forgings

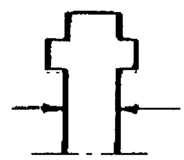
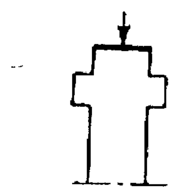
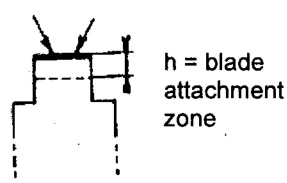
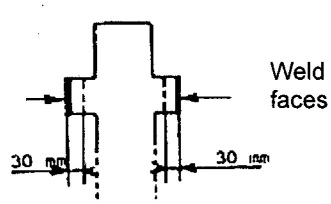
TABLE N°1

DEFINITION OF ACCEPTANCE CLASSES

Class	Reporting threshold max ∅ (mm)	Isolated indications max ∅ (mm)	Grouped indications max ∅ (mm)	Clustered indications max ∅ (mm)
S	0,5	1	0,7	0,5
C	1	2	1,5	1
O	1,6	3	2	1,6
1	1,6	5	3	2

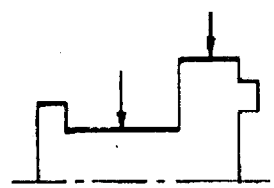
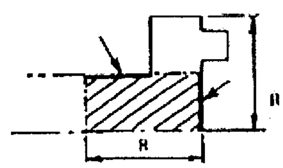
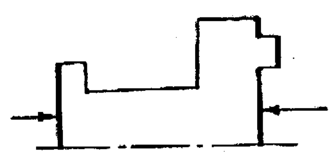
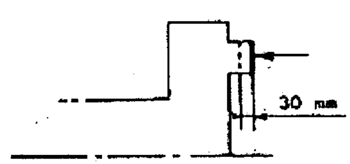
ATTACHMENT 1

Ultrasonic inspection of discs
Forgings for LP rotors

Item	Inspection – direction of probing	Probing method
1		- Straight beam
2		- Straight beam
3		- Angle probes – Transverse wave (Angles between 45° and 70°)
4		- S.E. probe

ATTACHMENT 2

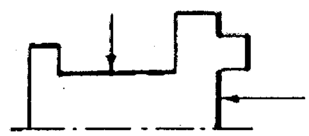
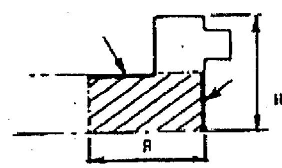
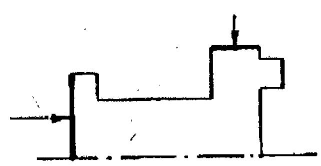
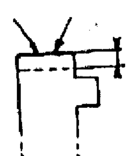
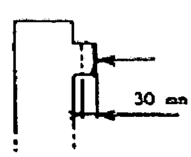
Ultrasonic inspection of shaft ends
Forgings for LP rotors

Item	Inspection – direction of probing	Probing method
1		- Straight beam
2		- Angle probes – Transverse wave Refraction angles chosen to suit geometry (in principle 45° and 60°)
3		- Straight beam
4		- S.E. probe

Note : the examination corresponding to item N°2 shall be carried out only in case of shaft ends where the balancing disc is obtained by upsetting.

ATTACHMENT 3

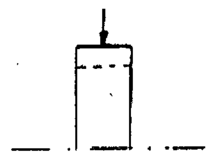
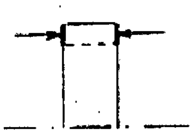
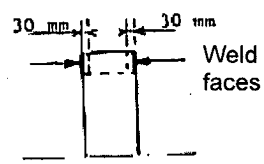
Ultrasonic inspection of shaft ends with integral disc Forgings for LP rotors

Item	Inspection – direction of probing	Probing method
1		- Straight beam
2		- Angle probes – Transverse wave Refraction angles chosen to suit geometry (in principle 45° and 60°)
3		- Straight beam
4	 h = blade attachment zone	- Angle probes – Transverse wave (angles between 45° and 70°)
5		- S.E. probe

Note : the examination corresponding to item N°2 shall be carried out only in case of shaft ends where the balancing disc is obtained by upsetting.

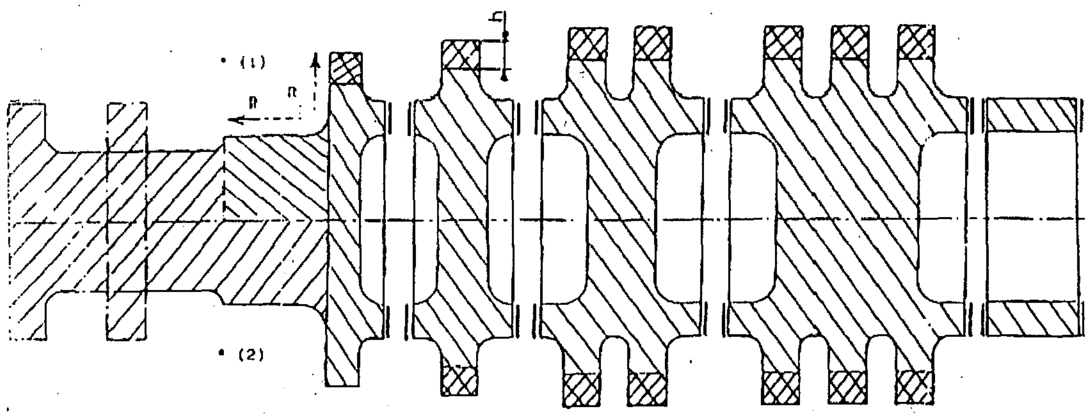
ATTACHMENT 4

Ultrasonic examination of rings
Forgings for LP rotors

Item	Inspection – direction of probing	Probing method
1		- Straight beam
2		- Straight beam
3		- S.E. probe

ATTACHMENT 5

Ultrasonic examination
LP rotor



LEGEND:

Classe C : Blade attachment area. Height is specified on inspection drawing cited in the purchase order.

Classe S : (Weld faces): 30 mm deep area adjacent to the designated front face

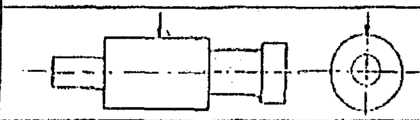
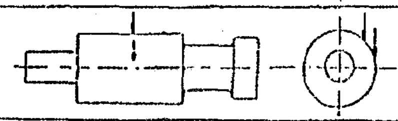
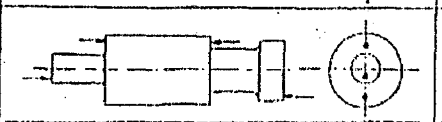
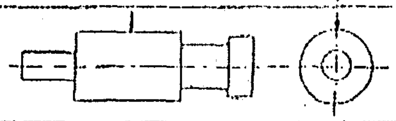
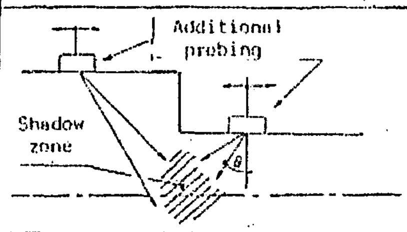
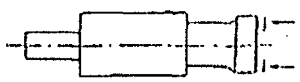
Classe 0

Classe 1

* (1) Shaft end with integral disc
* (2) Shaft end without integral disc

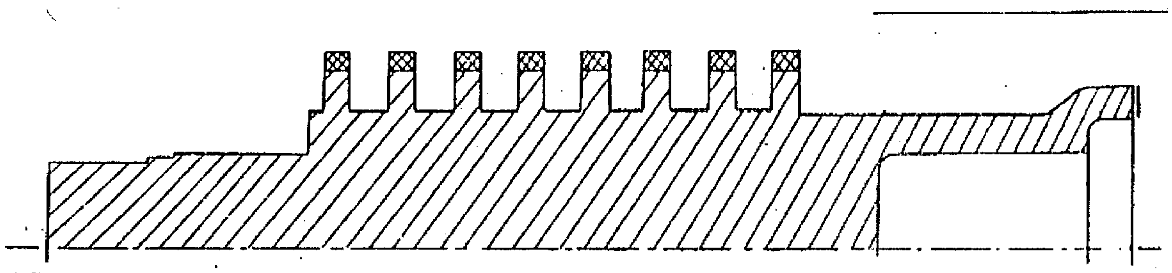
ATTACHMENT 6

Forgings for HIP rotors

Item	Examination Probe orientation	Probing method
1		Straight beam
2		Use of various shear-wave probes. Where φ designates the angle of divergence, the various angles of sound transmission α shall be such that: $\alpha_n = \alpha_{n-1} + 2\varphi$, where $\alpha_0 = 0°$ and $\alpha_{max} \le 70°$
3		Straight beam
4		Use of SE probes or shear-wave probes $\alpha = 70°$ (examination of the neck region)
5		Examinaton of shadow zones according to two probe orientations. The angles shall be selected according to the part geometry
6		Examination of the probing faces : region 30 mm deep in the vicinity of the front face designated |← Use of a suitable probe

ATTACHMENT 7

HIP rotor



KEY :

- Class C Region of blade attachment
- Class S (welding faces) : area 30 mm deep adjacent to the designated front face
- Class 0
- Class 1

HP ROTOR 1500 and 1000 rpm

Enclosure 2

Affidavit Attesting to Proprietary Nature of the ALSTOM Turbine Missile Analysis

AFFIDAVIT

COMMONWEALTH OF VIRGINIA)
) ss.
CITY OF RICHMOND)

1. My name is Stephen Reinstein. I am the Legal Counsel for the Power Systems Turbomachines Group of ALSTOM Power Inc. ("Alstom") and, as such, I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Alstom to determine whether certain Alstom information is proprietary. I am familiar with the policies established by Alstom to ensure the proper application of these criteria.

3. I am familiar with Alstom information contained in all the documentation associated with the Alstom Turbine Missile Analysis Report and referred to herein as "Documentation." Information contained in this Documentation has been classified by Alstom as proprietary in accordance with the policies established by Alstom for the control and protection of proprietary and confidential information.

4. This Documentation contains information of a proprietary and confidential nature and is the type customarily held in confidence by Alstom and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Documentation as proprietary and confidential.

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5. In order to satisfy the request of the U.S. Nuclear Regulatory Commission to be able to make available and release for public viewing a portion of the Documentation, Alstom has prepared a redacted version of the Documentation which excludes the information which Alstom considers to be proprietary. This redacted version is designated on each page as "Non-Proprietary Version". Alstom is hereby releasing the redacted or non-proprietary version of the Documentation to the U.S. Nuclear Regulatory Commission free of restrictions as to its publication.

6. The full version of the Documentation has, however, been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in the full version of the Documentation be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualified under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

7. The following criteria are customarily applied by Alstom to determine whether information should be classified as proprietary:

   (a) The information reveals details of Alstom's research and development plans and programs or their results.

   (b) The availability or use of any such confidential design information to or by a competitor of Alstom would provide such competitor with a substantial improvement in the ability to make competitive proposals that reflect knowledge of Alstom design effectiveness that is not otherwise available to the market. This competitive knowledge would allow such competitor to propose equipment performance with a greater than otherwise possible knowledge of Alstom's expected proposals, thereby improving the competitor's probability of selection and contract award.

(c) The information includes test data or analytical techniques concerning a process, methodology, component, or the detailed test results conducted on turbine equipment supplied by Alstom, which would provide to a knowledgeable reader, insights into the effectiveness of individual elements of Alstom's designs, as well as in depth knowledge of the actual performance of the complete equipment package, the application of which results in a competitive advantage for Alstom.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Alstom in product optimization or marketability. The use by a competitor of such information would be to the detriment of Alstom through the loss of contract awards, future sales and future profits. All such information is of great value to Alstom in its continuous design improvement process to meet the requirements of a competitive marketplace.

(e) The information is vital to a competitive advantage held by Alstom, would be helpful to competitors to Alstom, and would likely cause substantial and irreparable harm to the competitive position of Alstom. The information is of the type of information that Alstom zealously pursues

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and defends as confidential business information through the use of highly restrictive confidentiality agreements that are not time limited in their applicability.

The information in the full version of the Documentation is considered proprietary for the reasons set forth in paragraphs 6(b), 6(c), 6(d) and 6(e) above.

8. In accordance with Alstom's policies governing the protection and control of information, proprietary information contained in the full version of the Documentation has been made available, on a limited basis, to others outside of Alstom only as required and under stringent agreements providing for nondisclosure and limited use of the information.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

Stephen Reinstein, Legal Counsel

Subscribed before me this 13th

day of April, 2009.

Andrea Woods
Notary Public
My Commission Expires December 31, 2009
Commission No. 365754

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