UN'TED STATES OF AMERICA

DOCKETED

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD 81 NOV -2 P4:19

OFFICE OF SECRETARY DOCKETING & SERVICE BRANCH

In the matter of			
OFFSHORE POWER SYSTEMS		Docket No. S	STN 50-437
(Manufacturing License f Nuclear Power Plants)	for Floating		

AFFICAVIT OF

P. BLAIR HAGA REGARDING TURBINE-GENERATOR MATTERS

STATE OF FLORIDA)) ss. COUNTY OF DUVAL)

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I, P. BLAIR HAGA, being first duly sworn, do hereby depose and say:

DS03

Testimony on turbine generator matters was presented to the Board in hearing sessions during the period between December 8, 1976 and May 17, $1977^{/1}$. Since testimony was originally presented, additional technical information, which relates to the question of turbine missile, has been developed as a result of the following events:

- 1) Cracks were observed in low pressure discs in a number of operating nuclear turbines. $\frac{2}{2}$
- 2) Tests were conducted at the Electric Power Research Institute (EPRI) and Westinghouse Electric Corporation in which simulated discs at high speeds impacted with metal barriers. Data from these tests indicate that in some cases the energies with which missile fragments exit the wrbine casing may be higher than previously estimated. $\frac{3}{2}$
- 3) A disc failure occurred in the low pressure unit of the Yankee-Rowe Turbine Generator. $\frac{4}{-}$

For the reasons presented below none of the relevant conclusions put forth in prior testimony are invalidated by these events.

OBSERVATION OF DISC CRACKING

Subsequent to the conclusion of testimony on turbine-generator matters, cracks were discovered in the bore and keyways of a number of low pressure discs in operating turbines. The cracking phenomenon has been studied

/2 This was reported to the Board in Board Notification BN-80-1 from Mr. S. A. Varga, January 25, 1980.

/3 This has been the subject of the following memoranda and notices to the Board: S. M. Sohinki memorandum dated December 22, 1978; S. M. Sohinki memorandum dated January 2, 1979 and Loard notification BN-80-4, Mr. S. A. Varga, January 25, 1980.

/4 This was reported to the Board in Board Notification BN-80-8 dated February 19, 1980 and in a subsequent memorandum dated March 31, 1980, both from Mr. S. A. Varga.

^{/1} Tr. 4006 - 6001 and Tr. 6151-6172.

extensively by Westinghouse Electric Corporation, both to determine the mechanisms responsible for crack initiation and to estimate the time required for a crack to grow to the critical size at which disc failure could occur.

Westinghouse has concluded that the disc cracking was induced by stress corrosion and is developing design modifications to provide greater margin. These include:

- Affected discs have been redesigned to achieve lower bore stresses and utilize lower yield strength material.
- o Designs which eliminate bore keyways are now being utilized.
- Methods to keep the disc/bore keyways dry are being explored, since no cracking has been found in discs operating in dry steam.
- o Partial integral rotors where the first three discs are made a part of the shaft are being considered. Only the last few, less critical discs would have to be shrunk on in such a partial integral rotor.

At the present time there are no FNP turbines on order. Thus it is expected that significant design improvements will have been implemented by the time that the first turbine is manufactured.

In its study of turbine disc cracking in existing units, Westinghouse has also developed inservice inspection procedures and recommended intervals between inspection $\frac{5}{-}$. The recommended inspection intervals are based on observed crack size and are intended to assure that cracks will not grow to the critical size before the next inservice inspection. It was noted in prior testimony by both the Applicant and the Staff $\frac{6}{-}$ that the FNP turbines

^{/5} The Staff Safety Evaluation Report, "Criteria for Low Pressure Nuclear Turbine Disc Inspection" was transmitted to Westinghouse Steam Turbine Division by Mr. S. A. Varga's letter dated August 26, 1981.

^{/6} See for example the Staff's written direct testimony, pp. 32, 33 and Tr. 5534-5538.

will receive inservice inspection at approximately ten year intervals. This interval will be adjusted if necessary based initially on analyses of each FNP turbine using as-built data and subsequently on the results of each inservice inspection.

EPRI MISSILE PENETRATION TESTS

Additional test data on interaction between simulated turbine missiles and steel barriers have become available since May 1977. Tests performed at Sandia under EPRI sponsorship and additional tests performed by Westinghouse suggest the need to recalculate missile energy absorption by steel barriers such as the turbine casing. Westinghouse is in the process of recalculating the residual energy of disc fragments which penetrate the turbine casing. These calculations are being performed on each turbine utilizing as-buint data.

Results to date for machines similar to the FNP turbine show increased energy for some disc fragments. As part of its investigation into disc cracking, Westinghouse has estimated the probability of individual disc rupture at design conditions based on various inspection intervals for both existing and modified designs. Results of the calculations on existing Building Block 281 turbines indicate that the turbine failure probability assumed by Offshore Power Systems^{/7} will remain appropriate for disc no. 2 at speeds up to design overspeed considering appropriate inspection intervals. It is expected that the probability will be further reduced by design improvements. These calculations also indicate that failure probability of discs nos. 3, 4 and 5 will be substantially reduced. Failure of disc no. 1 at speeds up to design overspeed does not result in a missile.

Reanalysis of the FNP turbine is planned during the final design process. It is the judgment of Offshore Power Systems that when both the updated missile exit energy data and the disc rupture probability data are considered, the probability of damaging a vital target will be no greater than that stated in testimony presently before the Board for the design overspeed case.

None of the recently developed information affects the probability of occur ence of destructive overspeed. Thus, there is no impact on the previous conclusion of Offshore Power Systems that the probability of damage to a vital target from a destructive overspeed missile is less than 10" per year, because the probability of failure of the overspeed protection system is calculated to be on the order of 1×10^{-7} per demand. The Staff's analysis of destructive overspeed $\frac{8}{8}$ is based on a higher estimated probability of occurrence of destructive overspeed and therefore includes consideration of the probability of striking a vital target, given a missile. The Staff analysis considers three targets. In two cases (containment and main steam piping) the staff's calculation of strike probability depends only upon FNP geometry, i.e., it is assumed that a missile with the correct trajectory has adequate energy to reach the target. In the third case (spent fuel pool) the calculated strike probability depends upon missile energy in addition to geometric factors. However, the energy dependence is such that increased missile exit energy will not result in increased strike probability.

As a result of the foregoing, it is concluded that recent observations of disc cracking, missile penetration tests and revised Westinghouse exit energy calculations will not adversely affect the conclusions put forth in prior testimony respecting the probability of unacceptable damage from a turbine missile.

YANKEE-ROWE DISC FAILURE

On February 14, 1980, two discs in the low pressure unit of the Yankee-Rowe turbine generator failed with the turbine running at normal operating speed. The materials of the Yankee-Rowe turbine are similar to the Shippingport turbine, whose failure was addressed in prior testimony. Neither the Shippingport failure nor the Yankee-Rowe failure realted in missile formation. Both machines failed from stress corrosion cracking after many

^{\7} Calculations previously entered into evidence by both the Applicant and the Staff are based on an assumed value of P₁ (the probability of turbine missile generation) of 1 x 10⁻⁴/year from the Bush Report. \8 Staff's written direct testimony, pp. 2-11.

years of service, and in neither case did the failed turbine receive periodic ultrasonic disc inservice inspection.

The failure at Yankee-Rowe does not alter the conclusion in testimony presently before the Board that the FNP turbine is not expected to experience Shippingport-type failures.

The contents of this Affidavit were developed under my guidance, supervision and direction and are true and correct to the best of my knowledge, information and belief.

P. Blair Haga, Director Power Systems Pechnology

Sworn to and subscribed before me this 28th day of October 1981.

Notary Public, State of Florida at Large My Commission Expires: 10/05/82

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OFFSHORE POWER SYSTEMS	: Docket No. ST	N 50-437
	:	
(Manufacturing License for	:	
Floating Nuclear Power Plants)	:	

CERTIFICATE OF SERVICE

I hereby certify that copies of the "Affidavit of P. Blair Haga Regarding Turbine-Generator Matters" were surved upon the persons listed on Attachment 1 to this Certificate of Service by deposit in the United States mail, postage prepaid, this 28th day of October, 1981.

ohn R Kenvich

John R. Kenrick Counsel for Offshore Power Systems

ATTACHMENT 1

OPS SERVICE LIST

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