GE Nuclear Energy

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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Charles L. Miller, Director
Standardization and Non-Power Reactor Project Directorate

Subject: GE Responses to GE/NRC Materials & Chemical Engineering Branch Conference Call of April 30, 1991

Enclosed are thirty-four (34) copies of the GE responses to the discussion items of the subject call.

It is intended that GE will incorporate these responses in a future amendment.

Sincerely,

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cc: F. A. Ross (DOE)
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ADD1

RESPONSES TO MATERIALS & CHEMICAL ENGINEERING DISCUSSION ITEMS

DISCUSSION ITEM 1

Section 10.2.3.1 Material Selection

The staff recommends the following SRP 10.2.2.II.1 criteria be included in this section: The fracture appearance transition temperature (50% FATT) as obtained from Charpy tests performed in accordance with specification ASTM A-370 should be no higher than 0° for low-pressure turbine disks. The Charpy V-notch energy at the minimum operating temperature of each low-pressure disk in the tangential direction should be at least 60 ft-lbs.

RESPONSE 1

See revised Section 10.2.3.1 attached.

DISCUSSION ITEM 2

Section 10.2.3.2 Fracture Toughness

The applicant should clarify whether 115% of rated speed is the design overspeed for the low pressure turbine. The third paragraph in the section should include the following: Sufficient warnup time should be specified in the turbine operating instruction to assure that toughness will be adequate to prevent brittle fracture during startup.

SRP 10.2.3.II.2 recommends 4 acceptable methods to obtain fracture toughness properties. The applicant discussed one of the methods (method C) that was presented by J.A. Begley and W.A. Logsdon in Westinghouse Scientific Paper 71-1E7-MSLRF-P1.

However, the applicant should state that this method of obtaining fracture toughness, K_{IC}, should be used only on materials which exhibit a well-defined Charpy energy and fracture appearance transition curve and are strain-rate insensitive. The test data and the calculated toughness curve should be submitted to the NRC staff for review.

RESPONSE 2

See revised Section 10.2.3.2 attached.

DISCUSSION ITEM 3

Section 10.2.3.3 High Temperature Properties

Provide specific ASTM sections that were referenced in this section.

RESPONSE 3

Reference 2 was added to Section 10.2.3.3 and to revised Section 10.2.6 attached.

DISCUSSION ITEM 4

Section 10.2.3.4 Turbine Design

The following SRP 10.2.3 criteria should be included in this section:

a. The design overspeed of the turbine should be 5% above the highest anticipated speed resulting from a loss of load. The basis for the assumed design overspeed should be submitted to the staff for review.

b. The combined stresses of low-pressure turbine disk at design overspeed due to centrifugal forces, interference fit, and thermal gradients should not exceed 0.75 of the minimum specified yield strength in the weak direction of the materials if appropriate tensile tests have been performed on the actual disk material.

c. The turbine disk design should facilitate inservice inspection of all high stress regions, including bores and keyways, without the need fro removing the disks from the shaft (if shrunk-on disk rotors were used).

The applicant should clarify whether the low pressure turbines will have shrunk-on disks, welded disks, or forged disks.

RESPONSE 4

See revised Section 10.2.3.4 and new Section 10.2.5.2 attached.

DISCUSSION ITEM 5

Section 10.2.3.6 Inservice Inspection

SRP 10.2.3.5 recommends and the applicant commits to inservice inspection for the turbine disks at about 10-year intervals. However, in recent years, the staff has required applicants and licensees to use a probabilistic approach for scheduling the inspection of the low pressure turbine rotors with shrunk-on disks (NUREG-1048, "Safety Evaluation Report Related to the Operation of Hope Creek Generating Station Supplement No. 6,"July 1986). The turbine inspection program in the Hope Creek Generating Station is based on the General Electric Company proprietary report titled "Probability of Missile Generation in General Electric Nuclear Turbines", January 1984. This methodology has been reviewed by the NRC staff and found acceptable for use in establishing maintenance and inspection schedules for specific turbine systems.

The intent of the program evaluated in NUREG-1048 is to ensure that the probability of turbine missile generation is maintained less that $1x10^{-5}$ per year for an unfavorably oriented turbine and $1x10^{-4}$ per year for a favorably oriented turbine. The program takes into account specific turbine rotor operating conditions, material properties, results of periodic in-service inspections, and other factors. The program's determination of missile probability is based on the probabilities of individual parameters which may lead to the generation of the turbine missile. As a result, the program can facilitate evaluations of the effects of changes in any parameter. The probability of unacceptable damage from turbine missile should be maintained at less than or equal to $1x10^{-7}$ per year. Schedules for future inspection and replacement of low-pressure turbine rotors with shrunk-on discs should be based on the probabilistic approach.

RESPONSE 5

See item (6) of revised Section 10.2.3.4 attached.

Table 1.9-1

SUMMARY OF ABWR STANDARD PLANT INTERFACES WITH REMAINDER OF PLANT (Continued)

ITEM NO.	SUBJECT	INTERFACE TYPE	SUBSECTION
8.11	DC Voltage Analysis	Confirmatory	8.3.4.6
8.12	Seismic Qualification of Eyewash Equipment	Confirmatory	8.3.4.7
8.13	Diesel Generator Load Table Changes	Confirmatory	8.3.4.8
8.14	Offsite Power Supply Arrangements	Procedural	8.3.4.9
8.15	Diesel Generator Qualification Tests	Confirmatory	8.3.4.10
8.16	Defective Refurbished Circuit Breakers	Confirmatory	8.3.4.11
8.17	Minimum Starting Voltages for Class 1E Motors	Confirmatory	8.3.4.12
9.1	New Fuel Storage Racks Criticality Analysis	Confirmatory	9.1.6.1
9.2	New Fuel Storage Racks Dynamic and Impact Analysis	Confirmatory	9.1.6.2
9.3	Spent Fuel Storage Racks Criticality Analysis	Confirmatory	9.1.6.3
9.4	Spent Fuel Storage Rack Load Drop Analysis	Confirmatory	9.1.6.4
9.5	Ultimate heat sink capability	Design	9.2.17.1
9.6	Makeup water system capability	Design	9.2.17.2
9.7	Potable and Sanitary Water System	Design	9.2.17.3
9.8	Radioactive Drain Transfer System Collection Piping	Design	9.3.12.1
9.9	Contamination of DG Combustion Air Intake	Confirmatory	9.5.13.1
9.10	Use of Communication System in Emergencies	Procedural	9.5.13.2
9.11	Maintenance and Testing Procedures for Communication Equipment	Procedural	9.5.13.3
9.12	Fire Hazard Analysis Database	Confirmatory	9A.6.3
10.1	Low Pressure Turbine Disk Fracture Toughness	Confirmatory	10.2.5.1
10.2	Turbine Design Overspeed	Design	10.2.5.2

CHAPTER 10

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SECTION 10.2

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ILLUSTRATIONS

(5) Bearing metal and oil drain temperatures

(6) Shell temperature

(7) Valve positions

(8) Shell and rotor differential expansion

(9) Shaft speed, electrical load, and control valve inlet pressure indication

(10) Hydrogen temperature, pressure, and purity

(11) Stator coolant temperature and conductivity

(12) Stator-winding temperature

(13) Exciter air temperatures

(14) Turbine gland sealing pressure

(15) Gland steam condenser vacuum

(16) Steam chest pressure

(17) Seal oil pressure

10.2.2.7 Testing

The electrical and mechanical overspeed trip devices can be tested remotely at rated speed, under load, by means of lighted pushbuttons on the EHC test panel. Operation of the overspeed protection devices under controlled, overspeed condition is checked at startup and after each refueling or major maintenance outage.

Provisions for testing each of the following devices while the unit is operating are included:

(1) Main stop and control valves

(2) Turbine bypass valves

(3) Low pressure turbine combined intermediate valves (CIVs)

(4) Overspeed governor

(5) Turbine extraction nonreturn valves

(6) Condenser vacuum trip system

(7) Thrust bearing wear detector

(8) Remote trip solenoids

(9) Lubricating oil pumps

(10) Control fluid pumps

10.2.3 Turbine Integrity

10.2.3.1 Materials Selection

Turbine rotors and parts are made from vacuum melted or vacuum degassed Ni-Cr-Mo-V alloy steel by processes which minimize flaw occurrence and provide adequate fracture toughness. Tramp elements are controlled to the lowest practical concentrations consistent with good scrap selection and melting practice, and consistent with obtaining adequate initial and long-life fracture toughness for the environment in which the parts operate. The turbine materials have the lowest fracture appearance transition temperatures (FATT) and highest Charpy V-notch energies obtainable, on a consistent basis, from water quenched Ni-Cr-Mo-V material at the sizes and strength levels used. Since actual levels of FATT and Charpy V-notch energy vary depending upon the size of the part, and the location within the part, etc., these variations are taken into account in accepting specific forgings for use in turbines for nuclear application. Charpy tests are performed essentially in accordance with Specification ASTM A-370.

INSERT 10.2.3.1 ①

10.2.3.2 Fracture Toughness

Suitable material toughness is obtained through the use of selected materials as described in Subsection 10.2.3.1, to produce a balance of adequate material strength and toughness to ensure safety while simultaneously providing high reliability, availability, efficiency, etc. during operation.

Stress calculations include components due to centrifugal loads, interference fit, and thermal gradients where applicable. The ratio of material fracture toughness, K_{IC} (as derived from material tests on each major part or rotor), to the maximum tangential stress at speeds from normal to 115% of rated speed (the highest anticipated speed resulting from a loss of load is 110%) is at least 2 $\sqrt{inch}$. ② Adequate material fracture toughness needed to maintain this ratio is assured by destructive tests on

The design overspeed for the low pressure turbine is 115% of rated speed.

material samples using correlation methods which are as conservative, or more so, than those presented in Reference 1. ← INSERT 10.2.3.2a

Turbine operating procedures are employed to preclude brittle facture at startup by ensuring that metal temperatures are (a) adequately above the FATT, and (b) as defined above, sufficient to maintain the fracture toughness to tangential stress ratio at or above 2 $\sqrt{inch}$. ← INSERT 10.2.3.2b

10.2.3.3 High Temperature Properties

The operating temperatures of the high-pressure rotors are below the stress rupture range. Therefore, creep-rupture is not considered a significant failure mechanism.

Basic stress and creep-rupture data are obtained in standard laboratory tests at appropriate temperatures with equipment and procedures consistent with ASTM recommendations in Reference 2.

10.2.3.4 Turbine Design

The turbine assembly is designed to withstand normal conditions and anticipated transients, including those resulting in turbine trip, without loss of structural integrity. The design of the turbine assembly meets the following criteria:

(1) Turbine shaft bearings are designed to retain their structural integrity under normal operating loads and anticipated transients, including those leading to turbine trips.

(2) The multitude of natural critical frequencies of the turbine shaft assemblies existing between zero speed and 20 percent overspeed are controlled in the design and operation so as to cause no distress to the unit during operation.

(3) The maximum tangential stress resulting from centrifugal forces, interference fit, and thermal gradients does not exceed 0.75 of the yield strength of the materials at 115 percent of rated speed.

INSERT 10.2.3.4 → (4) & (5)

10.2.3.5 Preservice Inspection

The preservice procedures and acceptance criteria are as follows:

(1) Forgings are rough machined with minimum stock allowance prior to heat treatment.

(2) Each finished machined rotor is subjected to 100-percent volumetric (ultrasonic), and surface visual examinations, using established acceptance criteria. These criteria are more restrictive than those specified for Class 1 components in the ASME Boiler and Pressure Vessel Code, Sections III and V, and include the requirement that subsurface sonic indications are either removed or evaluated to ensure that they will not grow to a size which will compromise the integrity of the unit during its service life.

(3) All finished machined surfaces are subjected to a magnetic particle test with no flaw indications permissible.

(4) Each fully bucketed turbine rotor assembly is spin tested at 20-percent overspeed.

Additional preservice inspections include air leakage tests performed to determine that the hydrogen cooling system is tight before hydrogen is introduced into the generator casing. The hydrogen purity is tested in the generator after hydrogen has been introduced. The generator windings and all motors are megger tested. Vibration tests are performed on all motor-driven equipment. Hydrostatic tests are performed on all coolers. All piping is pressure tested for leaks. Motor-operated valves are factory leak tested and inplace tested once installed.

10.2.3.6 Inservice Inspection

The inservice inspection program for the turbine assembly includes the disassembly of the turbine and complete inspection of all normally inaccessible parts, such as couplings, coupling bolts, turbine shafts, low-pressure turbine buckets, low-pressure and high-pressure rotors. During plant shutdown coinciding with the inservice inspection schedule for ASME Section III components, as required by the ASME Boiler and Pressure Vessel Code, Section XI, turbine inspection is performed in sections during the refueling outages so that in 10 years total inspection has been completed at least once.

This inspection consists of visual and surface examinations as indicated below:

Since there is no nuclear safety related mechanical equipment in the turbine area and since the condenser is at subatmospheric pressure during all modes of turbine operation, failure of the joint will have no adverse effects on nuclear safety related equipment.

INSERT 10.2.5 (2) & (4) →

10.2.5 6 References

1. J. A. Begley and W. A. Logsdon, Westinghouse Scientific Paper 71-1E7 MSLRF-P1.

(3) 2. ASTM Section III, Vol 03.01, E139-83 Standard Practice for Conducting Creep, Creep Rupture and Stress Rupture Tests of Metallic Materials

INSERTS

INSERT 10.2.3.1

(1) The fracture appearance transition temperature (50% FATT) ad obtained from Charpy tests performed in accordance with specification ASTM A-170 will be no higher than $0^{\circ}F$ for low-pressure turbine disks. The Charpy V- notch energy at the minimum operating temperature of each low-pressure disk in the tangential direction should be at least 60 ft-lbs.

INSERT 10.2.3.2a

(2) However, this method of obtaining fracture toughness, K_{IC}, will be used only on materials which exhibit a well-defined Charpy energy and fracture appearance transition curve and strain-rate insensitive. The applicant referencing the ABWR design will provide the test data and the calculated toughness curve to the NRC staff for review. (See Subsection 10.2.5.1 for interface requirements)

INSERT 10.2.3.2b

(2) Sufficient warmup time should be specified in the turbine operating instruction to assure that toughness will be adequate to prevent brittle fracture during startup.

INSERT 10.2.3.4

(4) (4) The design overspeed of the turbine will be 5% above the highest anticipated speed resulting from a loss of load. The basis for the assumed design overspeed will be submitted to the NCR staff for review. (See Subsection 10.2.5.2 for interface requirements)

(4) (5) The combined stresses of low-pressure turbine disk at design overspeed due to centrifugal forces, interference fit and thermal gradients will not exceed 0.75 of the minimum specified yield strength of the material, or 0.75 of the measured yield strength in the weak direction of the materials if appropriate tensile tests have been performed on the actual disk material.

(5) (6) The turbine disk design will facilitate inservice inspection of all high stress regions, including bores and keyways. The turbine rotor design will be a solid forged monoblock rotor rather than shrunk-on disks.

INSERT 10.2.5

10.2.5 Interfaces

10.2.5.1 Low Pressure Turbine Disk Fracture Toughness

(2) The applicant referencing the ABWR design will provide turbine material property data and assure sufficient turbine warmup time as required by Subsection 10.2.3.2.

10.2.5.2 Turbine Design Overspeed

(4) The applicant referencing the ABWR design will provide the basis for the turbine design overspeed as required by Subsection 10.2.3.4(4).