Response to

Request for Additional Information No. 100 (1273), Revision 0

10/31/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 10.02.03 - Turbine Rotor Integrity
Application Section: 10.2.3

QUESTIONS for Component Integrity, Performance, and Testing Branch 1 (AP1000/EPR Projects) (CIB1)

Question 10.02.03-1:

The U.S. EPR FSAR, Tier 2 Section 10.2.3.1 specifies that the turbine rotors are made from vacuum melted or vacuum degassed Ni-Cr-Mo alloy steel and tramp elements are controlled to the lowest practical concentrations. In addition, Table 10.2-2 specifies that the high pressure (HP) turbine rotors are fabricated from material that has the nearest ASTM designation of ASTM A471, Class 2, and that the low pressure (LP) turbine rotor is 22CrNiMo 7-4 (which has no equivalent ASTM specification). The above does not provide sufficient information concerning the material used for the LP and HP turbine rotors in accordance with SRP Section 10.2.3 to assess its acceptability on the turbine rotor integrity. Therefore, the NRC staff requests the following information be provided:

a. Actual ASME or ASTM material specification that will be used, or the chemical composition ranges, including maximum levels of trace elements, and the corresponding mechanical properties of the materials.
b. Descriptions of the procedures used to minimize flaws, improve toughness and minimize chemical segregation.
a. Provide operating experience of these materials to demonstrate the acceptability of this material in turbine rotors, as stated in SRP Section 10.2.3, paragraph III.1.

Response to Question 10.02.03-1:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-2:

Specify in U.S. EPR FSAR, Tier 2 Section 10.2.3.1 the method for performing the tests for the fracture appearance transition temperature (FATT). For example, SRP Section 10.2.3 specifies testing in accordance with ASTM A370 is an acceptable method.

Response to Question 10.02.03-2:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-3:

Specify in U.S. EPR FSAR, Tier 2 Section 10.2.3.1 the number of Charpy V-Notch specimens that will be tested, and the method for performing the tests. For example, SRP Section 10.2.3 specifies testing of a minimum of 3 specimens in accordance with ASTM A370 is an acceptable method.

Response to Question 10.02.03-3:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-4:

The staff notes that Section 10.2.3.2 of the U.S. EPR FSAR, Tier 2 lists all four acceptable methods in SRP 10.2.3 for obtaining the fracture toughness properties of the turbine rotor. The staff requests that AREVA discuss the specific method that will be used for the particular U.S. EPR turbine rotor design in the FSAR.

Response to Question 10.02.03-4:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-5:

U.S. EPR FSAR, Tier 2 Section 10.2.3.2 states that stress calculations take into account loads and thermal gradients on all major components. In addition, the fracture mechanics calculations are performed on the rotors taking into account the maximum acceptable size defect for U.S. standards, and verifies that the initial defect, after increasing due to fatigue during the equipment lifetime does not propagate and remains non-critical by a large margin as regards to brittle fracture. Furthermore, Section 10.2.3.4 of the U.S. EPR FSAR only reiterates the acceptance criteria from SRP Section 10.2.3, paragraph II.4, but does not provide how these calculations meet the guidelines in the SRP.

a. Provide a schedule for the submittal of these calculations in order for the staff to complete a timely review of the design certification application.

b. Confirm that the stress calculations take into account stresses from the interference fit as specified in SRP Section 10.2.3, paragraph II.2.B.

c. Provide the maximum defect size used in the calculations.

d. Justify not using stress corrosion cracking as a degradation mechanism for crack growth of the initial defect in the calculations.

Response to Question 10.02.03-5:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-6:

The U.S. EPR FSAR, Tier 2 Section 10.2.3.1 specifies a forged turbine rotor while Section 10.2.3.4 states that the rotors are a welded design. Please provide the following information:

a. Clarify whether the turbine rotors are welded or forged.

b. Describe the assembly method of the rotor and blades, and if keyways are used.

c. If applicable, provide the standard used for welding (i.e., ASME Code, Section IX) and the typical weld joint used.

d. In addition, clarify Section 10.2.3.5, since it states that the rotors are forged or welded.

Response to Question 10.02.03-6:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-7:

U.S. EPR FSAR, Tier 2 Section 10.2.3.5 does not specify that welds in the turbine-rotor assembly are ultrasonically examined (preservice inspection) in the radial and radial-tangential sound beam directions as recommended in SRP Section 10.2.3. Provide the examination directions to be used for the ultrasonic examination in the FSAR. If they differ from SRP Section 10.2.3, provide justification that the intended examination will provide assurance of the structural integrity of the turbine-rotor assembly to prevent the generation of missile in accordance with GDC 4 of Appendix A of 10 CFR Part 50. In addition, specify whether the acceptance criteria in ASME Code, Section III, NB-2530 for plate or NB-2540 for forgings will be used.

Response to Question 10.02.03-7:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-8:

U.S. EPR FSAR, Tier 2 Section 10.2.3.5 does not specify the preservice inspection guidelines in SRP 10.2.3 for the finished bores, keyways, and drilled holes which are magnetic-particle or liquid-penetrant examined, and that no flaws are allowed in the keyway and hole regions. Justify not performing this inspection, and confirm that the elimination of this examination does not affect the assurance of the turbine rotor's structural integrity.

Response to Question 10.02.03-8:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-9:

U.S. EPR FSAR, Tier 2 Section 10.2.3.6 states that the turbine rotor inservice inspection program uses visual, surface and volumetric examination to inspect the turbine rotor assembly. It then lists the specific inservice inspection activities for the HP and LP turbine rotor assemblies, which is to be performed every 10 years and includes visual and surface examinations. However, there is no volumetric inspection (i.e., ultrasonic examination) listed.

In response to the staff's RAIs, AREVA stated that U.S. EPR FSAR, Tier 2 Section 10.2.3.6 will be changed to perform inservice inspections consistent with the inspection intervals from the turbine manufacturer's turbine missile analysis provided by the COL applicant. A COL applicant that references the U.S. EPR FSAR will provide a site-specific turbine rotor inservice inspection interval consistent with the turbine manufacturer's turbine missile analysis.

This still contradicts SRP Section 3.5.1.3 in that the U.S. EPR FSAR does not require a volumetric inspection to be performed, and that the COL applicant is not required to submit the turbine missile analysis. The wording proposed in AREVA's response to the staff's RAIs, only requires that the COL applicant provide the NRC with the inspection interval, and not the complete inservice inspection plan, which provides the extent of inspections, types of inspections, acceptance criteria, and inspection intervals.

a. Revise the COL Information Item 10.2-5 to provide a plant specific inservice inspection plan which includes the extent of inspection, types of inspection, acceptance criteria and frequency to be performed on the HP and LP turbine rotor assemblies that are consistent with the manufacturer's turbine missile analysis. The supporting manufacturer's turbine missile analysis will be provided for NRC for review and approval one year prior to initial fuel load.
b. Provide the volumetric inspection in section 10.2.3.6 as provided in the guidance of SRP Section 3.5.1.3.
c. COL Information item 10.2-1 specifies a COL applicant will provide a site-specific turbine rotor inservice inspection program for the alternate turbine (Section 10.2A.3). COL Information Item 10.2-1 should be clarified that it applies to either turbine design and to provide the site-specific turbine rotor inservice inspection program consistent with the turbine manufacturer's turbine missile analysis.

Response to Question 10.02.03-9:

A response to this question will be provided by January 30, 2009.

Question 10.02.03-10:

Table 2.8.1-3 of the U.S. EPR FSAR, Tier 1 provides the inspections, tests, analysis, and acceptance criteria (ITAAC) regarding the turbine rotor. There are two commitments numbered 1.0 in Table 2.8.1-3 of the U.S. EPR FSAR, Tier 1. Provide clarification and/or renumbering of the two ITAAC commitments 1.0.

Response to Question 10.02.03-10:

Turbine rotor ITAAC in U.S. EPR FSAR Tier 1, Table 2.8.1-3 will be renumbered as 1.0a and 1.0b. The associated design commitments in U.S. EPR FSAR Tier 1, Section 2.8.1.1.0 will be numbered as 1.0a and 1.0b.

FSAR Impact:

U.S. EPR FSAR Tier 1, Section 2.8.1 will be revised as described in the response and indicated on the enclosed markup.

Question 10.02.03-11:

In order for the staff to conclude that GDC 4 of 10 CFR Part 50, Appendix A is satisfied, the material, design, inspections and testing must satisfy the requirements in the manufacturer's turbine missile probability analysis. Therefore, the staff requests that the U.S. EPR FSAR, Tier 1, Table 2.8.1-3, Commitment 1.0 (first) be revised to include that the analysis for the turbine material property data, rotor and blade design, an pre-service and in-service inspection and testing meet the requirements of the manufacturer's turbine missile probability analysis.

Response to Question 10.02.03-11:

U.S. EPR FSAR Tier 1, Section 2.8.1, ITAAC 1.0a includes acceptance criteria for turbine material property data, rotor and blade design, and pre-service testing and inspection. U.S. EPR FSAR Tier 1, Section 2.8.1, ITAAC 1.0a acceptance criteria will be revised to meet the requirements of the manufacturer's turbine missile probability analysis.

FSAR Impact:

U.S. EPR FSAR Tier 1, Section 2.8.1 will be revised as described in the response and indicated on the enclosed markup.

Question 10.02.03-12:

The U.S. EPR FSAR, Tier 2 proposes to use a standard design turbine generator specified in Section 10.2, and an alternate design turbine generator specified in Section 10.2A. Table 1.8-2 of the U.S. EPR FSAR includes several of the following COL Information items specifically for the alternate turbine design:

> COL Information item 10.0-1 requires a COL applicant to select the turbine-generator design.
>
> COL Information item 10.2-1 requires a COL applicant to provide the site-specific turbine rotor inservice inspection program consistent with the recommendations of the manufacturer for the alternative turbine generator design.
>
> COL Information Item 10.2-4 requires a COL applicant that references the alternative turbine design provide a list of material specifications for the alternate turbine generator.

Currently, as evident by the above COL Information items, there is not enough information to reach a final conclusion on the safety issues related to turbine rotor integrity and prevention of generating turbine missiles in accordance with GDC 4 of Appendix A to 10 CFR Part 50 for the alternate turbine generator in the U.S. EPR FSAR. For example, since the material specification has not been determined for the alternate turbine design in Section 10.2A of the U.S. EPR FSAR, the staff can not review the acceptability of the material selection in accordance with SRP Section 10.2.3, paragraph III.1. Therefore, the alternate turbine design does not meet the requirement of 10 CFR 52.47 which states that the application for a design certification must contain a level of design information sufficient to enable the Commission to judge the applicant's proposed means of assuring that construction conforms to the design and to reach a final conclusion on all safety questions associated with the design before the certification is granted. 10 CFR 52.21(a) states that a standard design is sufficiently detailed and complete to support certification or approval in accordance with subpart B or E of this part, and which is usable for a multiple number of units or at a multiple number of sites without reopening or repeating the review. It is not clear how AREVA's proposal to specify an alternate turbine design meets the intent of the "standard design" definition in 10 CFR 52.21(a) with sufficient information to ensure that a final conclusion can be reached on all safety issues associated with that design as required by 10 CFR 52.47. Discuss how the use of your alternate turbine design meets the intent of 10 CFR Part 52 (Subpart B) for an essentially complete standard plant design.

Response to Question 10.02.03-12:

A response to this question will be provided by March 31, 2009.

Question 10.02.03-13:

U.S. EPR FSAR, Tier 2 Section 10.2A.3.1 (alternate turbine design) states that the Charpy tests will be in accordance with ASTM A370 or equivalent standard and that the nil-ductility transition temperature is obtained in accordance with specification ASTM E208-95a or equivalent standard. Specify the equivalent standards and provide the criteria used to determine that these standards are equivalent to ASTM A370 and ASTM E-208-95a, to ensure that the material properties are tested appropriately and consistently to prevent failure of the turbine rotor assemblies and the generation of potential missiles in accordance with GDC 4 of Appendix A to 10 CFR Part 50.

Response to Question 10.02.03-13:

A response to this question will be provided by March 31, 2009.

Question 10.02.03-14:

Verify that U.S. EPR FSAR, Tier 2 Section 10.2A.3.2 (alternate turbine design) should state that the ratio of the fracture toughness (KIC) of the rotor material to the maximum tangential stress at speeds form normal to design overspeed are at least "2 √in" in lieu of "2 in" in order to correct a typographical error.

Response to Question 10.02.03-14:

This is a typographical error. U.S. EPR FSAR Tier 2, Section 10.2A.3.2 will be revised to read "2 √in" in lieu of "2 in."

FSAR Impact:

U.S. EPR FSAR Tier 2, Section 10.2A.3.2 will be revised as described in the response and indicated on the enclosed markup.

Question 10.02.03-15:

U.S. EPR FSAR, Tier 2 Section 10.2A.3.2 and Section 10.2A.3.4 (alternate turbine design) states that low-pressure, shrunk-on disk rotors are designed to prevent stress-corrosion cracking through design features, material, quality, stress limitations and control of steam purity. Discuss the specific design features, material, quality, stress limitations and control of steam purity that are used for this alternate design and how it prevents the occurrence of stress-corrosion cracking. Also, provide supporting operating experience of this alternative turbine design.

Response to Question 10.02.03-15:

A response to this question will be provided by March 31, 2009.

Question 10.02.03-16:

Provide design details of the LP turbines (built-up rotor with the moving blades held in slots) and the HP turbines with a rotor of the forged, monobloc shaft with forged-on coupling flanges that are referenced in U.S. EPR FSAR, Tier 2 Section 10.2A.3.4 (alternate turbine design).

Response to Question 10.02.03-16:

A response to this question will be provided by March 31, 2009.

U.S. EPR Final Safety Analysis Report Markups

three C_v specimens are tested in accordance with specification ASTM A370, Reference 9, or equivalent standard.

A COL applicant that references the U.S. EPR design certification will provide applicable material properties of the turbine rotor after the site-specific turbine has been procured.

10.2A.3.2 Fracture Toughness

As noted in Section 10.2A.3.1, a suitable material toughness is obtained through the use of selected materials to produce a balance of adequate material strength and toughness and maintain a reasonable level of safety, while simultaneously providing high reliability, availability and efficiency during operation.

The low-pressure turbine disk rotor fracture toughness properties meet the following criteria.

10.02.03-14

The ratio of the fracture toughness (K_{Ic}) of the rotor material to the maximum tangential stress at speeds from normal to design overspeed are at least ~~2 in~~2 $\sqrt{in}$, at minimum operating temperature. Bore stress calculations include components due to centrifugal loads, interference fit and thermal gradients. Sufficient warm up time is specified in the turbine operating instructions to provide reasonable assurance that toughness is adequate to prevent brittle fracture during startup. Fracture toughness properties are obtained by any of the following methods:

- Testing of the actual material of the turbine rotor to establish the K_{Ic} value at normal operating temperature.
- Testing of the actual material of the turbine rotor with an instrumented Charpy machine and a fatigue precracked specimen to establish the K_{Ic} (dynamic) value at normal operating temperature. If this method is used, K_{Ic} (dynamic) is used in lieu of K_{Ic} (static) in meeting the toughness criteria.
- Estimating of K_{Ic} values at various temperatures from conventional Charpy and tensile data on the rotor material using methods are presented in J. A. Begley and W. A. Logsdon, Scientific Paper 71-1E7-MSLRF-P1 (Reference 5). This method of obtaining K_{Ic} is used only on materials which exhibit a well-defined Charpy energy and fracture appearance transition curve and are strain-rate insensitive.
- Estimating "lower bound" values of K_{Ic} at various temperatures using the equivalent energy concept developed by F. J. Witt and T. R. Mager, ORNL-TM-3894 (Reference 6).

Low pressure shrunk-on disk rotors are designed to prevent stress corrosion cracking through design features, material, quality, stress limitation and control of steam purity.

2.8 Steam and Power Conversion Systems

2.8.1 Turbine-Generator System

1.0 Description

The turbine-generator system is a non-safety-related system that converts the energy of the steam produced in the steam generators into mechanical shaft power and then into electrical energy.

The flow of steam is directed from the steam generators to the turbine through the main steam system, turbine stop valves, and turbine control valves. After expanding through the turbine, which drives the main generator, exhaust steam is transported to the main condenser.

10.02.03-10

Turbine overspeed control is provided by a separate turbine overspeed protection system, in addition to the normal speed control function, and is included to minimize the possibility of turbine rotor failure and turbine missile generation.

1.0a Turbine rotor integrity is provided through the combined use of selected materials with suitable toughness, analyses, testing, and inspections. Turbine rotor components and turbine stop and control valves will be inservice tested and inspected at intervals in accordance with industry practice or as specified by the manufacturer to meet turbine missile generation probability requirements.

1.0b The probability of turbine material and overspeed-related failures resulting in external turbine missiles is < 1×10^{-4} per turbine year.

2.0 Arrangement

2.1 The basic configuration of the turbine-generator system is shown in Figure 2.8.1-1—Turbine-Generator System Basic Configuration.

2.2 The orientation of the turbine-generator is favorable with respect to protection from turbine missiles.

2.3 The location of the turbine-generator system equipment is listed in Table 2.8.1-1—Turbine-generator System Equipment Mechanical Design.

3.0 Instrumentation and Controls (I&C) Design Features, Displays, and Controls

3.1 Controls exist in the main control room (MCR) to trip the turbine-generator.

3.2 Overspeed protection systems are listed in Table 2.8.1-2—Turbine-Generator System Equipment I&C and Electrical Design.

4.0 Electrical Power Design Features

4.1 Turbine stop valves and turbine control valves fail closed on loss of power.

Table 2.8.1-3—Turbine-Generator System Inspections, Tests, Analyses, and Acceptance Criteria (2 Sheets)

10.02.03-10

10.02.03-11

Commitment Wording		Inspection, Test or Analysis	Acceptance Criteria
1.0a	Turbine disk integrity is provided through the combined use of selected materials with suitable toughness, analyses, design, testing, and inspections.	An analysis of turbine rotor material property data, turbine rotor and blade design, and pre-service inspection and testing will be conducted. This information will be available for review greater than one year before loading the fuel.	An analysis exists that includes turbine material property data, rotor and blade design analyses (including loading combinations, assumptions and warm-up time) demonstrating sufficient safety margin to withstand loadings from overspeed events, and pre-service testing and inspection information (including scope, methods and acceptance criteria) meeting the requirements of the manufacturer's turbine missle probability analysis..
1.0b	The probability of turbine material and overspeed related failures resulting in external turbine missiles is < $1x10^{-4}$ per turbine year.	A material and overspeed failures analysis will be performed on the as-built turbine design.	An analysis exists that documents that the probability of turbine material and overspeed related failures resulting in external turbine missiles is < $1x10^{-4}$ per turbine year.
2.1	The basic configuration of the turbine-generator system is shown on Figure 2.8.1-1.	Inspections of the as-built system as shown on Figure 2.8.1-1 will be conducted.	The as-built turbine-generator system conforms with the basic configuration as shown in Figure 2.8.1-1.
2.2	The orientation of the turbine-generator is favorable with respect to protection from turbine missiles.	An inspection will be performed of the orientation of the turbine-generator.	The turbine-generator orientation is favorable relative to turbine missle protection.
2.~~2~~3	The location of the turbine-generator system equipment is in the Turbine Building.	An inspection will be performed of the location of the equipment.	The turbine-generator equipment is located in the Turbine Building.
~~4.1~~3.1	Controls exist in the MCR to trip the turbine-generator.	Tests will be performed for the existence of control signals from the MCR.	Controls exist in the MCR to trip the turbine-generator.