Response to

Request for Additional Information No. 45, Revision 0

8/21/2008

U. S. EPR Standard Design Certification
AREVA NP Inc.
Docket No. 52-020
SRP Section: 19 - Probabilistic Risk Assessment and Severe Accident Evaluation
Application Section: FSAR Ch 19
SPLB Branch

Question 19-189:

Zirconia is a very brittle material subject to failure by thermal shock as a result of the monoclinic-to-tetragonal phase change at about 1470 K.

a) Please demonstrate that the structural integrity of the Zirconia brick present in the cavity, the melt discharge channel, and the spreading compartment would be maintained in spite of the initial transient thermal loads that are expected following contact with molten core debris (i.e., following the molten core debris penetration of the 50 cm layer of siliceous, high iron-oxide content sacrificial concrete).

b) Discuss whether the Zirconia can be stabilized when materials such as MgO, CaO, and Y2O3 are produced during core debris-concrete interactions. In addition, address whether or not the exothermic dissolution of these materials has been evaluated as a possible contribution to the transient heat loads.

Response to Question 19-189:

While brittleness of the pure substance ZrO_2 occurs, the industrial use of zirconia is quite common and is due to the addition of stabilizers into the crystal lattice that prevent the described phase change or dampen its consequences. Naturally occurring zirconia undergoes a phase change between 1000°C and 1150°C and forms tetragonal ZrO_2 with a density of 6.1g/cm^3, which above 2350°C changes into cubic ZrO_2 with a density of 6.27g/cm^3 and a melting point of 2715°C. On heating and cooling, the large density difference between tetragonal and monoclinic ZrO_2 can lead to cracks in work pieces and components; therefore, in technological parts the cubic modification is stabilized. This is achieved by the addition of either CaO, MgO, or Y_2O_3 which form cubic mixed crystals with ZrO_2.

Partially stabilized ZrO_2 (stabilizers: MgO, CaO, Y_2O_3) is technologically important. At room temperature a large cubic phase with tetragonal areas exists, which is kept meta-stable; thus the change into the monocline phase is prevented. The elongation and density hysteresis on heating and cooling of zirconia is reduced by stabilization. Partly stabilized ZrO_2 has also a better fracture toughness than unstabilized ZrO_2.

Oxide ceramics are brittle and have a low resistance to thermal shock (Reference 1). The sensitivity to thermal-down shock is usually much higher than to thermal-up shock (References 2 and 3). In the U.S. EPR, the protective material experiences only a single, attenuated thermal-up shock, for the reasons described below.

The thermal shock behavior of oxide ceramics can be improved by adapting the microstructure (grain size distribution, pore size distribution, porosity) accordingly (References 3, 4, and 5). Coarse-grained zirconia material with relatively high porosity (e.g., 20 percent volume) exhibits better thermal shock resistance than material sintered to very high density. Partially stabilized zirconia with adapted microstructure is largely stable against temperature shocks due to the formation of micro-cracks which act as a buffer.

The reason for the toughness of stabilized zirconia is based on a percentage of the structure that goes through the tetragonal-to-monoclinic transformation when stress is applied. The volume expansion that accompanies this transformation occurs at the tip of the crack and changes the stress field at the tip of the crack, reduces the rate of crack propagation and improves its fracture toughness.

The resistance to thermal shock can be achieved even without full stabilization of the tetragonal or cubic phase of ZrO_2; thus, providing control of the density change at 1000°C. This structure suppresses the ZrO_2 volume changes sufficiently so that detrimental cracking is avoided.

Materials testing for the zirconia brick assembly identified for the U.S. EPR has been performed, including erosion tests for the contact with an oxidic core melt under molten corium-concrete interactions. From these tests it has been determined that the material is chemically stable and shock-resistant. A core melt, after contact, only infiltrates a very thin layer close to the surface; and that there are no uncharacterized exothermic reaction.

References for Question 19-189:

1. H. Salmang, H. Scholze, “Keramik - Teil 2: Keramische Werkstoffe,” Springer Verlag Berlin Heidelberg, 6. Auflage, 1982.

2. W.D. Kingery, J. Am. Ceram. Soc. 38, pp. 3-15, 1955.

3. W. D. Kingery, H. K. Bowen, D.R. Uhlmann, Introduction to Ceramics, John Wiley and Sons, New York, 1976.

4. K. Hesse, H.W. Hennicke, “Thermal-Shock-Resistant Zirconia (MgO-PSZ),” Ceram. Forum Int., 67, pp. 63-70, 1990.

5. P. Elstner, H. Jeschke, E. Leupold, J. Lührsen, “Use of Zirconium Oxide Materials in Plants for Making and Casting of Steel,” Stahl und Eisen, 100, pp. 1457-1462, 1980.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 19-190:

FSAR Section 19.2.6.4, on page 19.2-54, refers to Table 19.2-5 that lists SAMDA candidates already implemented in the U.S. EPR design. Specifically, SAMDA item CB-16, which has been implemented as part of the response to the guidance of SECY 93-087, is included in order to reduce or eliminate containment bypass leakage that could result from SGTR. On page 5-9, of Table 5-1, of the Environmental Report, (ANP-10290, Rev. 0) that supports the analysis presented in the FSAR, it is stated "the secondary side is cooled with feedwater supplied from the in-containment refueling water storage tank (IRWST)."

Please explain how this process is accomplished. Specifically, if this is already implemented, then it is important to evaluate whether this configuration could result in a new scenario for core damage with the potential for containment bypass.

Response to Question 19-190:

The feedwater source was incorrectly identified in the screening for SAMDA candidate CB-16 in Table 5-1 of ANP-10290, “AREVA NP Environmental Report Standard Design Certification.” The correct feedwater source is the deaerator/feedwater storage tank.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

ANP-10290, Table 5-1 will be revised as described in the response and indicated on the enclosed markup.

Question 19-191:

In FSAR Section 19.2.4.4.5.4, Reactor Building Annuls, on page 19.2-47, it is stated "the annulus is designed against a maximum overpressure of 16 psia, which is limited by the strength of the doors." Please clarify if the unit of "over-pressure" is meant to be "psia" or "psig".

Response to Question 19-191:

The annulus is designed against a maximum pressure of 16 psia (1.1 bar_a) or 1.5 psig (0.1 bar_g) overpressure.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

Question 19-192:

The NRC Staff assumes that the technical basis for severe accident management for U. S. EPR plants will be provided by AREVA. As outlined in Section 19.2.5 of the FSAR, it appears that this guidance is being developed in the Operating Strategies for Severe Accidents (OSSA) project. The technical basis needs to be reviewed by the NRC staff to ensure that the design-specific features for accident prevention and mitigation are appropriately considered, and that any potential issues or concerns are resolved before the applicable plant-specific procedures and training are developed.

Please identify a COL action item that would require a COL applicant to provide documentation of the severe accident management technical basis for NRC review. This documentation should include the following:

1. a discussion of the various sequences considered, and the range of possible challenges to accident mitigation;
2. the results of MAAP 4.0.7 analyses that support the development of the SAMGs;
3. the sets of high level and in-depth mitigation strategies to be used by the technical support center during a postulated severe accident.

It would also be necessary to confirm the necessary associated instrumentation and elaborate on the actions presented in Table 19.2-4 (and any other actions defined during the OSSA project), based on the MAAP results and the mitigation strategies.

Response to Question 19-192:

AREVA NP does not understand the regulatory basis of the question, as the information requested in the NRC question is not addressed in either RG 1.206 or SRP 19.2.

As noted in the response to RAI 3 on NRC approved topical report ANP-10286(P)(A), "U.S. EPR Severe Accident Topical Report," (Reference 1): "Specifics related to a severe accident management guidelines and strategy for the U.S. EPR will be addressed during detailed design." Severe accident management guidelines (SAMGs) are developed based on human factors considerations, the interfaces with the emergency operating procedures (EOPs), and emergency procedure guidelines (EPGs) in accordance with NUREG-0711, "Human Factors Engineering Program Review Model," and as described in U.S EPR FSAR, Tier 2, Chapters 13 and 18. This forms the basis for the development of the SAMGs, which will be available for NRC inspection upon completion.

U.S. EPR FSAR, Tier 1, Table 3.4-1—Human Factors Engineering Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) establishes ITAAC related to the development of the EOPs and EPGs. Further information on the process for developing the SAMGs is provided below.

The development of SAMGs is performed in several phases. The initial phase is dependent upon the establishment of the basic governing principles, scope, goals, and overall high level structure of the OSSA. This is achieved through the review of different existing approaches to severe accident management, including the review of international research and development and guidance on the preparation of severe accident management programs. In the second

phase, the list of severe accident challenge mechanisms is defined in more detail. In this phase, a comprehensive list of challenges is developed with specific reference to the U.S. EPR PRA Level 2 scenarios. From this list of challenges, the overall mitigation strategies are developed based on symptoms and phenomena, rather than specific scenarios. In support of the mitigation strategies, supplemental analyses are performed which demonstrate the effectiveness of the operator actions to the plant response. In the final phase, the overall mitigation strategies that will be used as guidance in the development of the actual SAMGs are documented along with a description of the plant instrumentation and setpoints that are to be used in mitigating severe accidents.

References for Question 19-192:

1. Letter, Ronnie L. Gardner (AREVA NP Inc.) to Document Control Desk (NRC), "Response to a Request for Additional Information Regarding ANP-10268P 'U.S. EPR Severe Accident Evaluation Topical Report' (TAC No. MD3803)," NRC:07:027, July 13, 2007.

FSAR Impact:

The U.S. EPR FSAR will not be changed as a result of this question.

ANP-10290 Markups

SAMDA ID	Potential Enhancement	Screening Criterion	Basis for Screening/Modification Evaluation
CB-10	Replace SGs with a new design.	Already Implemented	The U.S. EPR design includes SGs that use Alloy 690 tubing which has shown less propensity to stress corrosion cracking than generators with Alloy 600 tubing. Since this SAMDA was designed to decrease the frequency of tube rupture events by using the industry's best practices, it is concluded that this SAMDA is already implemented.
CB-11	Increase the pressure capacity of the secondary side so that an SGTR would not cause the relief valves to lift.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require more than $1,000,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($51,000) by more than a factor of 2. Therefore this SAMDA is not considered cost beneficial to implement in the U.S. EPR based on the results of this evaluation.
CB-12	Install a redundant spray system to depressurize the primary system during an SGTR.	Already Implemented	The U.S. EPR design has a normal pressurizer spray and an auxiliary spray. The auxiliary spray is part of the CVCS and is operational during loss of off-site power. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR.
CB-13	Proceduralize use of pressurizer vent valves during SGTR sequences.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-14	Provide improved instrumentation to detect SGTRs, such as Nitrogen-16 monitors.	Already Implemented	The U.S. EPR design incorporates instrumentation to detect SGTR. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR.
CB-15	Route the discharge from the MSSVs through a structure where a water spray would condense the steam and remove most of the fission products.	Excessive Implementation Cost	The cost of implementing a similar SAMDA at Arkansas Nuclear One Unit 2 was estimated by Entergy Operations to require $9,500,000 in 2005. The cost associated with the implementation of this SAMDA exceeds the attainable benefit for all SAMDAs ($51,000) by more than a factor of 2. Therefore, this SAMDA is not considered cost beneficial to implement in the U.S. EPR based on the results of this evaluation.
CB-16	Install a highly reliable (closed loop) SG shell-side heat removal system that relies on natural circulation and stored water sources.	Already Implemented	The SGs of the U.S. EPR are vertical shell, natural circulation, U-tube heat exchangers. The secondary side is cooled with feedwater supplied from the ~~in-containment refueling water storage tank (IRWST)~~deaerator/ feedwater storage tank. Therefore, the intent of this SAMDA is considered to have already been implemented for the U.S. EPR. 19-190
CB-17	Revise EOP to direct isolation of a faulted SG.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.
CB-18	Direct SG flooding after an SGTR, prior to core damage.	Not Required for Design Certification	This SAMDA is beyond the scope of the U.S. EPR Design Certification application.