Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

U.S. Nuclear Regulatory Commission
ATTENTION: Document Control Desk
Washington, D.C. 20555

Direct tel: 412-374-6206
Direct fax: 724-940-8505
e-mail: sisk1rb@westinghouse.com

Your ref: Docket No. 52-006
Our ref: DCP_NRC_002782

February 18, 2010

Subject: AP1000 Response to Proposed Open Item (Chapter 9)

Westinghouse is submitting the following responses to the NRC open item (OI) on Chapter 9. These proposed open item response are submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in these responses is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following proposed Open Item(s):

OI-SRP9.3.6-SRSB-0

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. A. Lindgren/FOR

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Proposed Open Item (Chapter 9)

D063
NRO

0435ljb.doc

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	P. Buckberg	-	U.S. NRC	1E
	T. Spink	-	TVA	1E
	P. Hastings	-	Duke Power	1E
	R. Kitchen	-	Progress Energy	1E
	A. Monroe	-	SCANA	1E
	P. Jacobs	-	Florida Power & Light	1E
	C. Pierce	-	Southern Company	1E
	E. Schmiech	-	Westinghouse	1E
	G. Zinke	-	NuStart/Entergy	1E
	R. Grumbir	-	NuStart	1E
	P. Loza	-	Westinghouse	1E

ENCLOSURE 1

AP1000 Response to Proposed Open Item (Chapter 9)

AP1000 TECHNICAL REPORT REVIEW

Response to SER Open Item (OI)

RAI Response Number: OI-SRP9.3.6-SRSB-01
Revision: 0

Question:

Fuel Corrosion and Crud Effects

According to TR-32 [APP-GW-GLN-002], the addition of zinc to the RCS could result in additional crud deposit on the fuel cladding surface. The applicant performed oxide thickness measurements that showed the crud deposit was thin and the effect of the corrosion rate with zinc injection was statistically insignificant as compared to the corrosion rate without zinc injection. In response to RAI-TR32-007, the applicant provided data from 12 fuel surveillance campaigns, based on which it concluded that there were no observed adverse effects on the fuel cladding performance due to zinc addition.

The staff reviewed the plant surveillance data for oxide thickness that were provided in the response to RAI- TR32-007 and agrees with the applicant's conclusion because there was no statistical difference in the measured oxide thickness for cladding with and without exposure to zinc in the coolant. Further, the staffs review of industry experience related to zinc impacts on fuel indicates there are no adverse effects for low to medium duty cores.

The applicant indicated that the absence of deleterious effects on cladding will be confirmed through cycle-specific reload analyses with zinc addition. The staff identified OI-SRP9.3.6-SRSB-01 for the applicant to explain how cycle-specific reload analyses can confirm no adverse effect of zinc addition for the AP1 000 with a high duty core and why a fuel surveillance program is not needed to confirm the absence of adverse crud effects.

Additional NRC clarification via email:

In Revision 17 of the AP1000 DCD, zinc addition is discussed as an option in Section 9.3.6.2.3.3. The detailed technical evaluation of zinc addition is contained in APP-GW-GLN-002 (TR32) Revision 0. The staff reviewed several reports documenting industry experience with zinc addition in PWRs, which indicate that there is no concern with crud deposition for plants with low-duty or medium-duty cores (Reference 1, 2).

However, there is currently insufficient operating experience with zinc addition in plants with high-duty cores to be able to conclude whether zinc injection could cause a problem with crud deposition in such plants. Potential problems with crud deposition could include excessively thick fuel crud, or uneven crud thickness that could lead to crud induced power shift (CIPS), also known as axial offset anomaly (AOA). Reference 2 recommends a fuel surveillance program for high-duty plants implementing zinc addition.

Plants with high-duty cores are those with high fluid temperatures and high surface heat flux at the fuel clad causing a portion of the total heat transfer to the coolant to occur by sub-cooled nucleate boiling (SNB). Although favorable for thermal efficiency, the combination of high temperature and SNB leads to more severe duty on the fuel, and surface boiling is known to enhance the formation of corrosion product deposits (crud) at the cladding surface. The High Duty Core Index (HDCI) is a measure of the duty on a core and is defined in Appendix F of Reference 3. Cores with an HDCI of ≥150 are considered to be high duty plants, medium duty plants have HDCI of 120-149, and a plant with HDCI ≤119 is considered a low-duty plant. It is not clear to the staff whether the AP1000 core is considered a high-duty core.

In the response to RAI-TR32-007, the applicant provided data on measured oxide thickness from 12 fuel surveillance campaigns from operating reactors, which showed no significant difference in oxide thickness for plants with and without zinc. TR-32 indicates that there are oxide thickness measurements for one high-duty plant. However, Reference 2 indicates that there has been relatively little experience with zinc addition at high duty plants through 2006.

TR-32 states that: "The results of oxide thickness measurements including a high-duty plant indicate that zinc does not have a statistically significant effect on cladding corrosion. This will be reconfirmed in cycle-specific reload analyses."

It is not clear to the staff how cycle-specific reload analyses would confirm that zinc would not have a significant effect on cladding corrosion.

1. Is the AP1000 core design as described in DCD Revision 17 considered a high-duty core?

2. If the AP1000 is considered a high-duty core design, how will it be assured that there will not be problems with excessive crud buildup or uneven crud buildup in operating AP1000 plants? This answer may necessitate either operating experience that demonstrates that a fuel surveillance program is unnecessary, or a recommendation for a fuel surveillance program to be implemented (COL Item).

3. Explain how cycle-specific reload analyses would confirm that zinc would not have a significant effect on cladding corrosion.

4. Since one of the objectives of zinc addition is to reduce the potential for CIPS, will an evaluation of CIPS potential be performed as part of the cycle-specific reload analysis? If so, provide details of the evaluation and a relative comparison to operating plants with and without CIPS. Also, since zinc injection will initially increase the reactor coolant Ni concentration, explain in detail the zinc injection strategy to be employed to minimize the CIPS potential.

References:

1. Overview Report on Zinc Addition in Pressurized Water Reactors—2004, 1009568 Final Report, December 2004, Electric Power Research Institute

2. Pressurized Water Reactor Primary Water Zinc Application Guidelines 1013420 Final Report, December 2006, Electric Power Research Institute

3. PWR Axial Offset Anomaly (AOA) Guidelines, Revision, 1008102, Final Report, June 2004, Electric Power Research Institute

Westinghouse Response:

Introduction:

Westinghouse has a long history related to zinc addition and CIPS. We have worked with EPRI on zinc addition for over 15 years and specifically related to CIPS for over 10 years. We were key contributors to the EPRI guidelines and methodology included in the above references for these questions.

Addressing the specific questions:

1. **Is the AP1000 core design as described in DCD Revision 17 considered a high-duty core?**

   Response: According to EPRI HDCI, AP1000 would be classified as a low to medium duty plant. The core parameters used in determining the HDCI for AP1000 and the HDCI values are included in the following Table:

Input Parameter	Value
Vessel Outlet Temperature*	610°F
Tsat @ 2250 psi	653°F
Peak assembly power (a)	1.42 – 1.45
Number of assemblies	157
Number of rods/assembly	264
Core power	3400 MWth
Active Fuel Height	14 ft
Total flow	315,000 gpm
Derived Values	
Core power (BTU/hr)	1.160E10
Total fuel surface area	56,816
Average heat flux (BTU/hr-ft2)	204,168
Assembly flow (gpm)	2,006

Peak assembly heat flux (BTU/hr-ft2)	204,168 * a
HDCI	
For a = 1.42	120 BTU/ft2-gal-°F
For a = 1.45	123 BTU/ft2-gal-°F

* It is important to use vessel outlet temperature, not core outlet temperature, in this evaluation. The EPRI model internally accounts for the difference between vessel outlet temperature and core exit temperature.

However, since in terms of boiling duty for AP1000 is approaching that of other Westinghouse high duty plants, we are conservatively treating AP1000 as a high duty plant. There are other currently operating PWRs that are higher duty, so AP1000 is bounded by current operating experience.

2. **If the AP1000 is considered a high-duty core design, how will it be assured that there will not be problems with excessive crud buildup or uneven crud buildup in operating AP1000 plants? This answer may necessitate either operating experience that demonstrates that a fuel surveillance program is unnecessary, or a recommendation for a fuel surveillance program to be implemented (COL Item).**

   Response: Zinc addition is being employed to reduce RCS surface corrosion rates beginning from hot functional testing. Experience with zinc addition in current PWRs following steam generator replacement indicates substantial benefits in reducing corrosion rates when zinc is applied to fresh metal surfaces such as those found following steam generator replacement. Papers on first cores show similar benefits will occur with AP1000, but right from the beginning of plant operation.

   When the EPRI zinc addition guidelines (Reference 2 above) were issued in 2006, the zinc addition experience in high duty plants was somewhat limited. High duty plant experience with zinc addition began in 2003, but has increased rapidly in the last several years, and high duty plants such as Callaway, Vogtle 1 and 2, Byron 2, Braidwood 2, South Texas 1 and 2, Watts Bar 1 have successfully operated with zinc addition and no problems with crud deposition or fuel performance related to zinc. Fuel examinations following zinc addition have been completed at numerous high duty PWRs and continue to show no increase in cladding corrosion and no deleterious impact on fuel crud deposits.

   AP1000 will have a very robust fuel inspection program looking not only at crud but other things using EPRI fuel reliability guidelines related to INPO 0 by 10 initiatives.

3. **Explain how cycle-specific reload analyses would confirm that zinc would not have a significant effect on cladding corrosion.**

   Response: Zinc has been shown not to interact with zircaloy clad fuel and does not increase clad corrosion. Reload-specific corrosion analyses do not need to be penalized due to zinc addition because as zinc began to be applied to higher duty cores additional fuel surveillance was undertaken to determine if any increased cladding corrosion was occurring. The surveillances have not shown any indication of enhanced clad corrosion for zinc application in these higher duty cores where crud deposits were present.

   As discussed below, a cycle specific reload analysis will consider the effect of the plant and core design, and zinc addition strategy on expected crud thickness and will demonstrate that the reload designs should not result in excessively thick crud deposits.

4. **Since one of the objectives of zinc addition is to reduce the potential for CIPS, will an evaluation of CIPS potential be performed as part of the cycle-specific reload analysis? If so, provide details of the evaluation and a relative comparison to operating plants with and without CIPS. Also, since zinc injection will initially increase the reactor coolant Ni concentration, explain in detail the zinc injection strategy to be employed to minimize the CIPS potential.**

   Response: A CIPS risk analysis is currently performed using EPRI guidelines and methods for every reload design performed in Westinghouse. This process will be performed as part of the initial core and each reload core analysis for AP1000.

   The VIPRE/BOA methods will be used as recommended in your Reference 3 (AOA guidelines).

   As zinc was originally added to operating PWRs beginning after many years of plant operation where the RCS surfaces and steam generator tubes had existing oxide layers, the potential for zinc to interact with these existing corrosion films and displace nickel from them was identified. However, subsequent plant RCS nickel concentration measurements have not shown any increase in coolant nickel concentrations. The expectation that zinc might displace nickel from the existing corrosion films was limited to plants with mature corrosion films on the RCS surfaces. For fresh metal surfaces, lab testing and plant experience, including replacement SG and first cores, has indicated that zinc is incorporated directly into the corrosion films as they form, making them thinner and more resistant to further corrosion. As such, zinc is a benefit when applied to fresh metal surfaces such as a new plant, or a plant replacing steam generators. Zinc reduces ongoing corrosion of those surfaces. This in turn reduces coolant corrosion product concentrations and reduces crud buildup on the fuel. No increase in coolant nickel concentrations resulting from zinc addition are expected for AP1000.

Zinc addition will be applied to the RCS during hot functional testing before the fuel is present in the RCS. This allows the maximum benefits of zinc to be attained by immediately conditioning the RCS surface and steam generator tubing surfaces to reduce corrosion. The zinc concentration will be reduced when fuel is in the core and will be similar to concentrations currently used in other high duty PWRs operating with zinc addition.

Design Control Document (DCD) Revision: None

PRA Revision: None

Technical Report (TR) Revision: None