AP1000 DOCUMENT COVER SHEET

TDC: ______ Permanent File: ______ APY: ______

RFS#: ______ RFS ITEM #: ______

AP1000 DOCUMENT NO.	REVISION NO.		ASSIGNED TO
APP-GW-GLN-002	0	Page of	W-A. Sterdis

ALTERNATE DOCUMENT NUMBER: WORK BREAKDOWN #:

ORIGINATING ORGANIZATION: Westinghouse Electric Company

TITLE: Zinc Addition

ATTACHMENTS:	DCP #/REV. INCORPORATED IN THIS DOCUMENT REVISION:
CALCULATION/ANALYSIS REFERENCE:	

ELECTRONIC FILENAME	ELECTRONIC FILE FORMAT	ELECTRONIC FILE DESCRIPTION
GLN002	Microsoft Word	

ORIGINATOR	SIGNATURE/DATE	
T. Meneely	[signature] 4/4/06	
REVIEWERS	SIGNATURE/DATE	
VERIFIER	SIGNATURE/DATE	VERIFICATION METHOD
D. A. LINDGREN	[signature] 4/5/06	PAGE BY PAGE REVIEW
AP1000 RESPONSIBLE MANAGER	SIGNATURE*	APPROVAL DATE
J. Winters	[signature]	4/5/06

* Approval of the responsible manager signifies that document is complete, all required reviews are complete, electronic file is attached and document is released for use.

Document Number: APP-GW-GLN-002 **Revision Number:** 0
Title: Zinc Addition

Brief Description of the change (what is being changed and why):
The ability to inject a small quantity of zinc acetate into the Reactor Coolant System has been incorporated into the AP1000 design. Operation with chemical zinc in the coolant has been demonstrated to change the oxide film on primary piping and components, significantly reducing occupational radiation exposure and the potential for crud-induced power shift (CIPS, formerly AOA).

Zinc addition will be an optional mode of operation, and the equipment specifically used for storing and pressurizing the zinc acetate is not described herein. However, minor changes to the base AP1000 design are required to allow for zinc addition to be used, particularly in reactor coolant water chemistry specification (DCD Table 5.2-2) and the Chemical and Volume Control System (DCD section 9.3.6). These changes are described in this report.

I. APPLICABILITY DETERMINATION

This evaluation is prepared to document that the change described above is a departure from Tier 2 information of the AP1000 Design Control Document (DCD) (Reference 1) that may be included in plant specific FSARs without prior NRC approval.

A.	Does the proposed change include a change to:		
	1. Tier 1 of the AP1000 Design Control Document APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a report for NRC review of the changes)
	2. Tier 2* of the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a report for NRC review of the changes)
	3. Technical Specification in Chapter 16 of the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a report for NRC review of the changes)
B.	Does the proposed change involve:		
	1. Closure of a Combined License Information Item identified in the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare a COL item closure report for NRC review.)
	2. Completion of an ITAAC item identified in Tier 1 of the AP1000 Design Control Document, APP-GW-GL-700	☒ NO ☐ YES	(If YES prepare an ITAAC completion report for NRC review.)

☒ The questions above are answered no, therefore the departure from the DCD does not require prior NRC review unless review is required by the criteria of 10 CFR Part 52 Appendix D Section VIII B.5.b. or B.5c

II. TECHNICAL DESCRIPTION AND JUSTIFICATION

1.0 Introduction

To support the proposed zinc addition to the reactor coolant, Westinghouse has performed evaluations for operating plants which confirm that zinc addition up to 40 ppb will not adversely affect any component or system in the reactor coolant system. See, for example, LTR-REA-05-10, (Reference 2) for details.

Nuclear fuel considerations for zinc addition will be addressed as part of fuel delivery documentation. If a plant utilizes zinc addition starting with hot functional testing, no known fuel limitations exist. If zinc addition is not used during initial fuel cycles but is initiated later in plant life, some temporary restrictions may be required on coolant zinc concentrations, as determined as part of core reload analyses.

The addition of the zinc compound will be carried through piping in the chemical and volume control system that is also used to supply hydrogen into the reactor coolant returned to the reactor coolant system. To optimize the delivery of the zinc compound and hydrogen into the reactor coolant return line, a portion of the line is changed to a smaller diameter, thicker wall pipe. This will substantially reduce the volume of the pipe and the transit time for the addition of the zinc and hydrogen. The air-operated containment isolation valve on this line is changed from normally closed to normally open to reflect the time that the valve must be open to permit zinc addition. The containment requirements for the valve are not changed.

2.0 Evaluation

RCS exclusive of nuclear fuel:

The addition of zinc to the reactor coolant system of a pressurized water reactor (PWR) is performed as a means to inhibit general corrosion and primary water stress corrosion cracking (PWSCC) of primary system materials and components. Zinc addition has also been demonstrated to be effective in reducing radiation fields in a number of United States and European plants.

Laboratory tests indicate a beneficial effect of zinc addition on the major materials in a PWR system (e.g. Alloy 600, Alloy 690, 304 and 316 stainless steels, and Stellite) in that the corrosion rates are reduced. The corrosion rates of the materials are reduced by about a factor of three or more with the addition of 20 ppb of zinc. The current understanding is that this effect is the result of modification of the oxide corrosion films that develop on system materials in the coolant containing zinc. Zinc addition results in thinner oxide films and modifies the structure and morphology of these spinel corrosion films. This leads to the preferential release of nickel and cobalt by the substitution of zinc for these elements in the spinel lattice.

The characteristics of the zinc modified oxide film makes it more protective, with respect to additional corrosion of the underlying base metal, but in all other aspects and properties essentially unchanged. With respect to non-destructive examination techniques, there is no difference between the corrosion films and zinc addition does not adversely affect or change in-service inspection or steam generator eddy current testing measurements. Laboratory tests of chromium plated type 316 stainless steel baffle bolting and Neolube lubricant under simulated service loads showed no effect of zinc added to the test coolant. Operating experience has shown that the presence of zinc in the reactor coolant system of PWRs, at zinc concentrations up to 40 ppb, has no apparent effect on the safe and reliable operation of any primary system components. Additionally, no reactor coolant system material problem has been related to zinc in PWRs with zinc addition.

Metallic zinc in containment can undergo reactions that generate hydrogen. However, in solution in the primary coolant and when incorporated into corrosion films, zinc exists as divalent cations and not neutral zinc atoms. In a post-LOCA scenario zinc residuals from reactor coolant system zinc addition can not liberate hydrogen. In addition, even if it were conservatively assumed that all of this zinc reacted to generate hydrogen, much less than one cubic foot of hydrogen could be introduced into containment from this source.

The effect of zinc on the reactor coolant was calculated to be very small, between 0 and +0.02 pH units. This effect is judged to be negligible. The effect on the sump pH is even smaller, because the volume of reactor coolant in the reactor coolant system is a small fraction of the borated water volume entering the sump.

Two potential concerns were identified relative to the boron dilution event. The first concern is that the zinc addition path would increase the assumed dilution flowrate, and second, the zinc addition path represents a new dilution source, potentially increasing the chance for a boron dilution event to occur. For both concerns, the potential dilution flowrate of 189 ml/min (about 0.05 gpm, conservatively higher than anticipated), is insignificant relative to the dilution flowrates assumed in the boron dilution. This will have no effect on the results of the analysis.

Zinc addition will result in an increase in ^{65}Zn concentration in the primary coolant if natural zinc is used. This increase in ^{65}Zn concentration has no impact on radiological consequences of the design basis accidents reported in the AP1000 DCD. The increase in ^{65}Zn releases would remain a very small fraction of total releases and would result in only an insignificant increase in overall effluent concentrations relative to the 10 CFR Part 20 concentration limits.

Nuclear fuel:

The addition of zinc to the reactor coolant system can result in the formation of a thin dark deposit on the surface of the fuel rods at the end of the cycle. The results of crud scraping, rod brushing and eddy current lift-off re-measurements, as well as observations of the ease with which the black deposit is removed, suggest that this deposit is very thin.

The results of oxide thickness measurements including a high duty plant indicate that zinc does not have a statistically significant effect on cladding corrosion (Reference 3). This will be reconfirmed in cycle-specific reload analyses.

As a result of a reduction in corrosion release rates, the long-term risk of crud induced power shift (axial offset anomaly) is expected to be lowered as a result of zinc addition.

Supply line changes

The change of a portion of the H2 supply/zinc addition piping from downstream of the containment isolation valve to the reactor coolant return line will replace a 1-inch diameter pipe with a heavier wall 1/2-inch pipe. This will substantially reduce the volume of this portion of pipe and reduce the transit time for the supply of hydrogen and zinc compound. This change will not alter the loads on the supply piping or connecting piping. The pressure boundary integrity of the piping is not adversely affected.

Document Number: APP-GW-GLN-002 **Revision Number:** 0
Title: Zinc Addition

The addition rates of hydrogen and the zinc compound in solution are relatively low. At the low velocities expected any coaxial flow of the hydrogen and zinc compound is expected to have no significant instability.

Because the addition of zinc is expected to occur over longer period of time than is typical for hydrogen addition, the containment isolation valve on the supply line is considered to be a normally open valve when used for zinc supply. The existing containment isolation function signal associated with the isolation valve is not altered for the use with zinc addition. The size and type of valve and operator are not changed. The designation of the valve as an active valve in DCD table 3.9-12 is not altered. The safety-related mission, safety functions and inservice testing type and frequency designated for valve inservice test requirements in Table 3.9-16 are not altered. The information about valve functions and requirements for the containment isolation valve in Tier 1 Table 2.3.2-1 is not altered.

References:

1. APP-GW-GL-700, AP1000 Design Control Document, Revision 15
2. LTR-REA-05-10, February 4, 2005, Vogtle Unit 2, Primary System Zinc Addition Engineering Evaluation
3. Westinghouse Letter NF-GP-04-47, Zinc Injection effects on ZIRLO™ Clad Fuel, July 1, 2004
4. NUREG-1793, Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, September 2004.

III. DCD MARK-UP

The following markups show changes to be incorporated relative to the AP1000 DCD, Revision 15.

Add a row for specification for zinc and a Note 7 to Table 5.2-2 as shown below

Table 5.2-2

REACTOR COOLANT WATER CHEMISTRY SPECIFICATIONS

Magnesium(6)	0.025 ppm, maximum
Zinc(7)	**0.04 ppm maximum**

Notes:

7. **Specification is applicable during power operation when zinc is being injected. The zinc concentration is maintained at the lower of 0.04 ppm or that specified I the reload safety analysis.**

Document Number: APP-GW-GLN-002 **Revision Number:** 0

Title: Zinc Addition

In Table 6.2.3-1 revise the CVS H2 injection to RCS line isolation devise to be normally open as shown below:

Table 6.2.3-1 (Sheet 1 of 4)

CONTAINMENT MECHANICAL PENETRATIONS AND ISOLATION VALVES

	Containment Penetration			**Isolation Device**			
System	**Line**	**Flow**	**Closed Sys IRC**	**Valve/Hatch Identification**	**DCD Subsection**	**Position N-S-A**	
CVS	H2 injection to RCS	In	No	CVS-PL-V092 CVS-PL-V094	9.3.6	~~CO-C-C~~ C-C-C	...

Document Number: APP-GW-GLN-002 **Revision Number:** 0

Title: Zinc Addition

Revise the third paragraph of 9.3.6.2.1 as follows:

> The mixed bed demineralizers are provided in the purification loop to remove ionic corrosion products and certain ionic fission products; **they also remove zinc during periods of zinc addition**. The demineralizers also act as filters. One mixed bed is normally in service, with a second demineralizer acting as backup in case the normal unit should become exhausted during operation. Each demineralizer and filter is sized to provide a minimum of one fuel cycle of service without changeout.

Add a new Subsection 9.3.6.2.3.3 as follows:

9.3.6.2.3.3 Zinc Addition

> **A soluble zinc compound may be added to the coolant as a means to reduce radiation fields within the primary system and to reduce the potential for crud-induced power shift (CIPS). The zinc used may be either natural zinc or zinc depleted of ^{64}Zn.**

Revise Figure 9.3.6-1 to include the following changes:

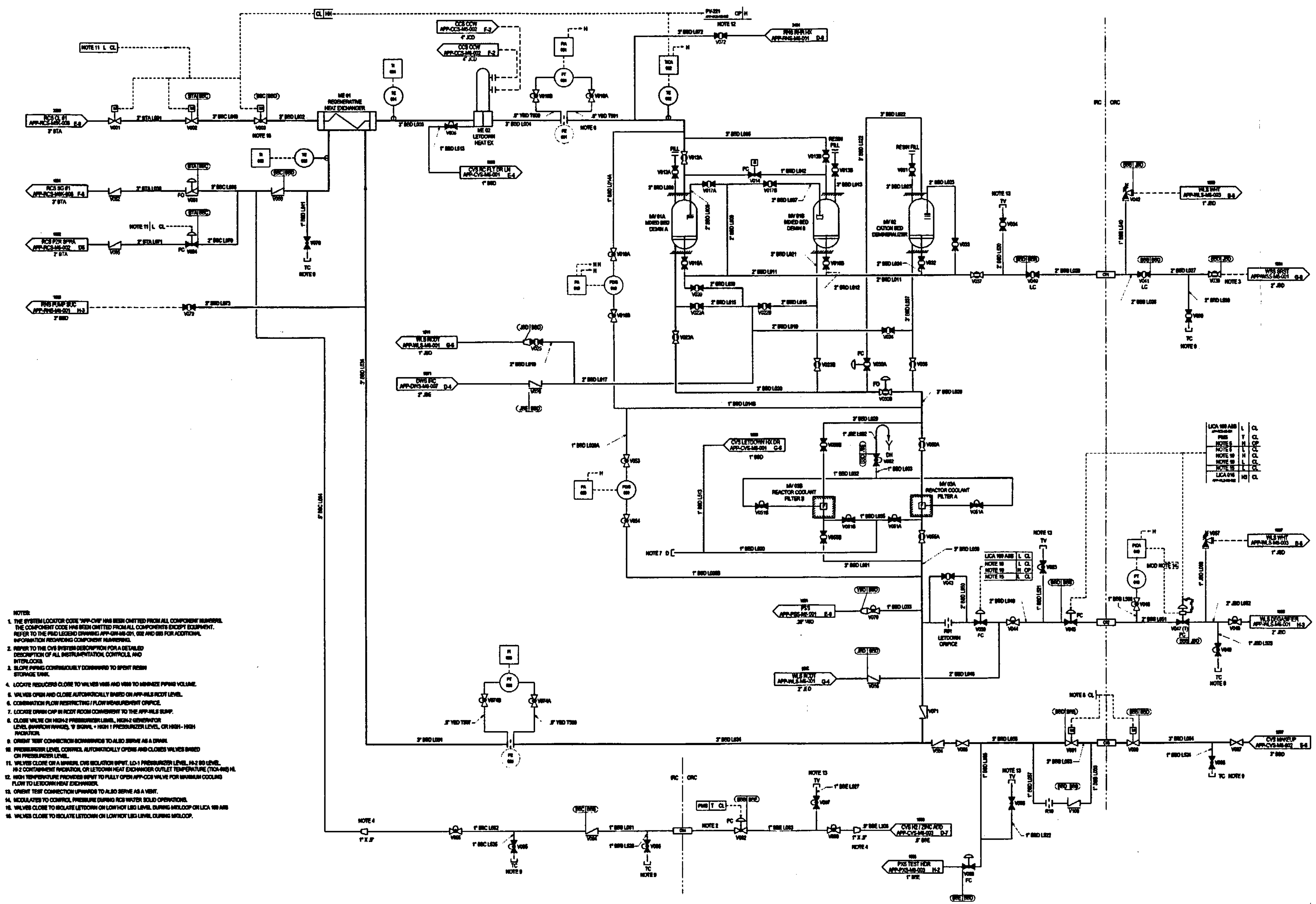
- Valve V092 is changed to normally open.
- A reducer is added down stream of Valve V065.
- The portion of the H2/ZINC ADD line from the reducer o the return line is renumbered as L064.
- The specification of L064 is changed to .5" BBC.

as shown on the following page:

Document Number: APP-GW-GLN-002 **Revision Number:** 0

Title: Zinc Addition

APP-CVS-M6-001



IV. REGULATORY IMPACT

A. FSER IMPACT

The FSER (Reference 4) discusses the chemical volume and control system in Subsection 9.3.6. This change has no impact on the text or conclusions of AP1000 FSER Subsection 9.3.6. The FSER discusses the containment isolation system in Subsection 6.2.4. This change has no impact on the text or conclusions of AP1000 FSER Subsection 6.2.4. The FSER discusses reactor coolant pressure boundary integrity in Section 5.2. This change has no impact on the text or conclusions of AP1000 FSER Subsection 5.2.

B. SCREENING QUESTIONS (Check correct response and provide justification for that determination under each response)

1. Does the proposed change involve a change to an SSC that adversely affects a DCD described design function? ☐ YES ☒ NO

The pressure boundary design function of the reactor coolant system and connecting systems that contain reactor coolant is not altered by the zinc addition. Experience in operating plant including visual fuel exams and oxide thickness measurements indicate no negative effects on the fuel due to zinc addition. The design functions of the line used for the addition of the zinc compound and associated valves including containment isolation are not altered.

2. Does the proposed change involve a change to a procedure that adversely affects how DCD described SSC design functions are performed or controlled? ☐ YES ☒ NO

Zinc addition will not affect the manner in which the plant is operated and will not require changing the normal operation of the reactor coolant system or supporting systems. The operating procedures used to startup and shutdown the plant and to respond to operational transients and postulated accident conditions are not adversely affected by the operation of the zinc addition system. The zinc addition is compatible with procedures used to monitor and control reactor coolant water chemistry.

3. Does the proposed activity involve revising or replacing an DCD described evaluation methodology that is used in establishing the design bases or used in the safety analyses? ☐ YES ☒ NO

The methods used to evaluate the response of the plant to postulated accident conditions are not changed by zinc addition. The methods used to evaluate the reactor coolant pressure boundary are not changed by zinc addition. The methods used to evaluate the radiation dose rate, including the method used to calculate coolant radioactive material contaminant parameters, are not changed by the zinc addition. The addition of ^{65}Zn into the radiation dose analysis is consistent with the existing methodology and constitutes no change in the methodology.

The methods used to evaluate the fuel cladding, relative to Design Basis Limit for a Fission Product Barrier (DBLFPB) as described in the DCD do not specifically address zinc concentration in the RCS.

The fuel performance models do not have to be modified to account for zinc addition.

4. Does the proposed activity involve a test or experiment not described in the DCD, where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the DCD? ☐ YES ☒ NO

   The plant, including the RCS, will not be utilized or controlled in a manner that is outside the reference bounds of the design for the plant regarding zinc addition.

C. EVALUATION OF DEPARTURE FROM TIER 2 INFORMATION (Check correct response and provide justification for that determination under each response)

   10 CFR Part 52, Appendix D, Section VIII. B.5.a. provides that an applicant for a combined licensee who references the AP1000 design certification may depart from Tier 2 information, without prior NRC approval, if it does not require a license amendment under paragraph B.5.b. The questions below address the criteria of B.5.b.

1. Does the proposed departure result in more than a minimal increase in the frequency of occurrence of an accident previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The use of zinc addition does not change the frequency of an accident because zinc addition is not an initiator of any accident. Zinc addition does not increase the initiation or progression of corrosion in primary pressure boundary materials. Zinc addition will not increase the frequency of accidents that may result from primary pressure boundary degradation such as pipe or tube ruptures. The use of a small volume of water to carry the zinc solution will not increase the potential for a boron dilution event. Zinc addition does not introduce a new failure mode in components that would result in an accident previously evaluated.

2. Does the proposed departure result in more than a minimal increase in the likelihood of occurrence of a malfunction of a structure, system, or component (SSC) important to safety and previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The use of zinc addition does not introduce the possibility of a change in the likelihood of a malfunction because zinc addition is not an initiator of any malfunctions. The inclusion of zinc in corrosion films will not adversely affect the operation of pumps and valves. The addition of zinc will not adversely alter heat transfer or flow rates in equipment relied on to cool or transfer reactor coolant. Zinc addition does not introduce a new failure mode in equipment relied upon to prevent or mitigate design basis accidents.

   Changing operating procedures to include stopping the zinc addition during shutdown of the plant will not increase the likelihood of occurrence of a malfunction of the chemical and volume control system or other SSC important to safety.

3. Does the proposed departure Result in more than a minimal increase in the consequences of an accident previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

The use of zinc addition does not introduce the possibility of a change in the consequences of an accident. The increase in concentration of the ^{65}Zn releases or release of species associated with the oxide film would remain a very small fraction of total releases and would not result in calculated releases exceeding analysis limits. Zinc addition does not change the response of the reactor coolant system and engineered safeguard systems to postulated accident conditions.

There is no impact on post-accident hydrogen buildup in containment. The presence of zinc in the reactor coolant will have a negligible effect on post-accident hydrogen generation.

The additional dilution flow of 0.05 gpm resulting from the zinc addition process is considered to be small relative to the dilution flows assumed in the licensing basis analyses and will not change the results or conclusions of the analyses or DCD.

At the planned zinc addition levels, the fuel meets fuel rod design limits with zinc addition; therefore, the number of fuel rod failures assumed and predicted in safety analyses will not increase.

4. Does the proposed departure result in more than a minimal increase in the consequences of a malfunction of an SSC important to safety previously evaluated in the plant-specific DCD? ☐ YES ☒ NO

   The use of zinc addition does not introduce the possibility of a change in the consequences of a malfunction because zinc addition will not cause pumps, valves, and heat exchangers to malfunction and result in a larger release to the environment. Zinc addition has no effect on systems and components used to mitigate the consequences of postulated accidents.

   Changing operating procedures to include stopping the zinc addition during shutdown of the plant will not increase the consequences of a malfunction of the chemical and volume control system or other SSC important to safety.

5. Does the proposed departure create a possibility for an accident of a different type than any evaluated previously in the plant-specific DCD? ☐ YES ☒ NO

   The use of zinc addition does not introduce the possibility of a new accident because zinc addition is not an initiator of any accident and zinc addition does not introduce a new failure mode in systems that provide fission product barriers and mitigate postulated accidents. Zinc addition will not change the manner in which the operator controls the plant or responds to transients or accident conditions. Any postulated effect of zinc addition on the integrity of the pressure boundary would be bounded by previously evaluated pipe breaks. The addition of zinc into the reactor coolant will not alter the response of the reactor coolant system or engineered safeguards systems to transient conditions. The addition of excessive water by the zinc addition into the reactor coolant system is bounded by boron dilution evaluations.

   The use of zinc addition does not introduce the possibility of a new accident with respect to the fuel because zinc addition is not an initiator of any accident and zinc addition does not introduce a new failure mode in the fuel. The addition of zinc into the reactor coolant will not alter the response of the fuel to transient conditions.

Document Number: APP-GW-GLN-002 **Revision Number:** 0

Title: Zinc Addition

6. Does the proposed departure create a possibility for a malfunction of an SSC important to safety with a different result than any evaluated previously in the plant-specific DCD? ☐ YES ☒ NO

   The use of zinc addition does not introduce the possibility for a malfunction of an SSC with a different result because addition of zinc does not change the operation or function of systems and components and does not introduce a new failure mode in systems and components. Clearances and dimensions in the core are not altered by the zinc addition. The inclusion of zinc in corrosion films will not adversely affect the operation of pumps, valves, heat exchangers, etc.

7. Does the proposed departure result in a design basis limit for a fission product barrier as described in the plant-specific DCD being exceeded or altered? ☐ YES ☒ NO

   The use of zinc addition does not result in a change that would cause a system parameter to change. There is a beneficial effect on the primary pressure boundary corrosion. Although there is no evidence to date (Reference 5), nuclear fuel cladding corrosion can potentially be impacted by zinc addition.

   The reduction in corrosion rate of the primary pressure boundary will have no effect on the stresses in the reactor coolant pressure boundary. The fuel performance design evaluation models are not changed by zinc addition and the design basis limit will not be exceeded or altered. Therefore, zinc addition does not result in a design basis limit for a fission product barrier as described in the DCD being exceeded or altered.

8. Does the proposed departure result in a departure from a method of evaluation described in the plant-specific DCD used in establishing the design bases or in the safety analyses? ☐ YES ☒ NO

   The methods used to evaluate zinc addition do not constitute a departure from a method of evaluation described in the DCD. Standard versions of the previously approved methodologies, all of which are described in the DCD, were used to support the conclusions drawn in this evaluation.

☒ The answers to the evaluation questions above are "NO" and the proposed departure from Tier 2 does not require prior NRC review to be included in plant specific FSARs as provided in 10 CFR Part 52, Appendix D, Section VIII. B.5.b

☐ One or more of the answers to the evaluation questions above are "YES" and the proposed change requires NRC review.

D. IMPACT ON RESOLUTION OF A SEVERE ACCIDENT ISSUE

10 CFR Part 52, Appendix D, Section VIII. B.5.a. provides that an applicant for a combined licensee who references the AP1000 design certification may depart from Tier 2 information, without prior NRC approval, if it does not require a license amendment under paragraph B.5.c. The questions below address the criteria of B.5.c.

1. Is there is a substantial increase in the probability of a severe accident such that a particular severe accident previously reviewed and determined to be not credible could become credible? ☐ YES ☒ NO

Document Number: APP-GW-GLN-002 **Revision Number:** 0
Title: Zinc Addition

The changes have no effect on the operation, performance, and pressure boundary integrity of the reator coolant system and connected systems. Therefore, there is no effect on the calculation of the probability of a severe accident.

2. Is there is a substantial increase in the consequences to the public of a particular severe accident previously reviewed? ☐ YES ☒ NO

   The changes have no effect on the operation, performance, and pressure boundary integrity of the primary pressure boundary. Therefore, there is no effect on the calculation of the release of radioactive material during a severe accident.

☒ The answers to the evaluation questions above are "NO" and the proposed departure from Tier 2 does not require prior NRC review to be included in plant specific FSARs as provided in 10 CFR Part 52, Appendix D, Section VIII. B.5.c

☐ One or more of the he answers to the evaluation questions above are "YES" and the proposed change requires NRC review.

E. SECURITY ASSESSMENT

1. Does the proposed change have an adverse impact on the security assessment of the AP1000? ☐ YES ☒ NO

   The change to permit zinc addition will not alter barriers or alarms that control access to protected areas of the plant. The change to permit zinc addition will not alter requirements for security personnel.

Preparer: Timothy K Meneely [signature] Date: 4/5/2006
(Print name) (Sign)

Reviewer: D.A. LINDGREN [signature] Date: 4/5/2006
(Print name) (Sign)