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

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Our ref: DCP_NRC_002779

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Subject: AP1000 Response to Request for Additional Information (SRP 3)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 3. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response 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 RAI(s):

RAI-SRP3.8.2-CIB1-01 R3
RAI-SRP-3.8.2-SEB1-03 R1

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. O. Lindgren /FOR

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

/Enclosure

1. Response to Request for Additional Information on SRP Section 3

D063
NRO

cc:	D. Jaffe	-	U.S. NRC	1E
	E. McKenna	-	U.S. NRC	1E
	B. Gleaves	-	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
	D. Lindgren	-	Westinghouse	1E

ENCLOSURE 1

Response to Request for Additional Information on SRP Section 3

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP3.8.2-CIB1-01
Revision: 3

Question:

Tier 2, Section 3.8.2.6 of the AP1000 DCD, describes the materials used to fabricate the containment vessel. The material selected satisfies the lowest service metal temperature requirement, established by analysis for the portion of the vessel exposed to the environment when the ambient air temperature is -40 °F. Westinghouse Technical Report APP-GW-GLN-113 (TR-113), "AP1000 Containment Vessel Shell Material Specification," Revision 0, submitted by Westinghouse letter dated May 11, 2007, revised this section by replacing the material specification Supplementary Requirement S17 with Supplementary Requirement S1 concerning the material fabrication process. However, Revision 16 to AP1000, Section 3.8.2.6 was changed to specify the lowest service temperature of -18.5 degrees F instead of -15 °F which was previously stated in Revision 15 of the AP1000 DCD. TR-113 did not specify the change to the service temperature nor provided any justification for this change in service temperature as required by 10 CFR 52.63(a)(1). In NUREG-1793, Section 3.8.2.6, the NRC staff approved -15 °F as the lowest service temperature based on the staff review of Westinghouse calculation APP-PCS-M3C-002, Revision 1, "AP1000 Containment Shell Minimum Service Temperature." Therefore, provide the reason and justification for the change in minimum service temperature of the containment vessel in accordance with 10 CFR 52.63(a)(1), and the analysis that supports the new service temperature proposed in Revision 16 of the AP1000 DCD.

Additional Question (Revision 1)

In a letter dated July 22, 2008, Westinghouse stated that an additional scenario was postulated for the containment vessel shell analysis, which determined that the containment vessel will be subjected to a service metal temperature of -18.5 °F. This evaluation postulated that an SSE event occurred in conjunction with -40 °F outside temperature and inadvertent actuation of active containment cooling. Westinghouse Technical Report APP-GW-GLR-005 (TR-9) only describes the analysis, and inadvertently did not include the corresponding service metal temperature.

Since TR-9 does not include the analysis or the service metal temperature, the NRC staff cannot confirm that -18.5 °F is the lowest service metal temperature of the containment vessel shell, which is fabricated from SA-738 Grade B material. This material must meet the requirements of NE-2000 for fracture toughness (Charpy V-notch test) in the as-welded condition for thicknesses up to and including 1.75 inches, and in the post-weld heat treated condition for thicknesses greater than 1.75 inches. The minimum service temperature is used to determine the testing temperature for the Charpy V-notch tests required by ASME Code, Section III, Subsections NE-2300 and NE-4300. Previously, Westinghouse stated in its letter dated April 22, 2003, that the SA-738, Grade B plate material will be procured using the service metal temperature of -15 °F (i.e., -55 °F Charpy V-notch test temperature as required by ASME

Code, Section III, Subsections NE-4335.2(b)(2) and Tables NE-4622.7(b)-1, note (2)(b)(1) in order to account for degradation during welding of the heat affected zone in the base material). In addition, Westinghouse stated in a letter dated March 13, 2003, that the previous analysis added an 8 °F conservative factor to obtain a minimum service metal temperature of -15 °F.

Therefore, the NRC staff requires additional information to verify the minimum service metal temperature. This information includes the details of the analysis (e.g., calculation methodology, assumptions made, similarities/differences from previous analysis, etc.) to confirm that -18.5 °F is the lowest service metal temperature to ensure that the material will be tested to have adequate toughness for the design and environment the containment shell will experience. Also, clarification is needed of whether the conservative factors described in the Westinghouse letter dated March 13, 2003, were also used in this analysis. Otherwise, justification for not including these conservative factors should be included

***Additional Question (*Revision 2)**

The response to RAI-SRP 3.8.2-CIB1-01 Rev. 1 was inadequate because it did not provide the information specifically requested in the last paragraph of the Rev. 1 Additional Question. This includes details of the analysis (e.g., calculation methodology, assumptions made, similarities/differences from previous analysis, etc.) and a discussion of the conservatisms.

Additional Question (Revision 3)

1) Please provide a plot of the containment shell temperature response in cold conditions discussed in the RAI response, similar to Figure E-1 provided in response to RAI-SRP-6.2.1.1-SPCV-07 (e). This plot covers the part of the transient used to establish steady-state initial conditions

2) Is the minimum service metal temperature of -18.5 ºF in the AP1000 DCD based on the steady state result or the additional transient scenario discussed in your response to RAI-SRP-6.2.1.1-SPCV-07?

Westinghouse Response: (Revision 0)

An evaluation of AP1000 containment vessel, in the vicinity of large penetrations, was performed by Westinghouse to meet the requirements of COL Information Item 3.8-1. During this evaluation an additional scenario was postulated for the containment vessel shell analysis. The AP1000 plant is designed for sites that can have cold weather conditions with a minimum atmospheric temperature of -40 °F. Therefore, an SSE event was postulated to occur in conjunction with extreme cold weather condition (-40 °F outside temperature) and inadvertent actuation of active containment cooling. The analyses results were documented in an AP1000 calculation. The analyses determined that during this event, the containment vessel will be subjected to an external pressure of 0.9 psid and a 'Service Metal Temperature' of -18.5 °F.

Westinghouse Technical Report APP-GW-GLR-005 submitted to the NRC described these analyses in subsection 2.4.1 of the report. Also, in Table 3.8.2-1 'Load Combinations', at the end of the report, a reference was added for this event. This Table showed the external pressure of 0.9 psid, but inadvertently did not include the corresponding 'Service Metal Temperature' of -18.5 °F.

This change will be incorporated in the next revision of the DCD.

Additional Response (Revision 1):

The Revision 0 change indicated was made in DCD Rev 17.

The additional information required to verify the minimum service metal temperature is provided in Westinghouse document APP-MV50-Z0C-020. Rev 0. This document is made available for review in the Twinbrook office, and provides support for the Lowest Service Metal Temperature of -18.5 °F, corresponding to -40 degree F outside temperature.

Additional Response (Revision 2)

The original calculation supporting a minimum shell temperature of -15 °F represented a simple radial heat balance. The model is shown below:

q" = h-in * (Tcont – Twall-in) (1)

q" = k/x * (Twall-in – Twall-out) (2)

q" = h-out * (Twall-out – Tamb) (3)

where	q"	is the average heat flux through the shell wall
	h-in	is the average heat transfer coefficient between the containment atmosphere and the inside wall of the shell
	Tcont	is the average containment atmosphere temperature
	Twall-in	is the average temperature of the shell inside surface
	Twall-out	is the average temperature of the shell outside surface
	k	is the steel shell thermal conductivity
	x	is the thickness of the steel shell
	h-out	is the average heat transfer coefficient between the outside surface of the containment shell and the air in the annulus
and	Tamb	is the average temperature of the air in the annulus

For this calculation, the following values were used:

h-in =	1.0 Btu/hr/ft^2/°F	based on free convection
Tcont =	50 °F	lower containment limit
k =	30 Btu/hr/ft/°F	carbon steel thermal conductivity
x =	1.75 in	containment average thickness
h-out =	2.6 Btu/hr/ft^2/°F	based on mixed forced/free convection (Ref. 1)

Solving equations 1-3 simultaneously,

Twall-in = -14.7 °F

Twall-out = -15.1 °F

This is the basis for the -15 °F shell temperature reported previously.

For the more detailed calculation, the WGOTHIC computer code was used. The correlations used to calculate the heat transfer coefficients on the shell surfaces were slightly different than those used in the simplified model. Essentially, the free/forced convection model used on the outside surface resulted in a slightly higher heat transfer coefficient which, in turn, resulted in a lower shell temperature. WGOTHIC calculates a heat transfer coefficient of

h-out = 3.18 Btu/hr/ft^2/F

The radial heat balance performed by WGOTHIC results in an average outside shell temperature of -18 °F

References:

1. Holman, J.P., *Heat Transfer*, 4th Ed, McGraw-Hill, 1976.

The conservatisms used for the WGOTHIC calculation are those inherent in the WGOTHIC code and not necessarily those in the March 13, 2003 letter. The conservative factors described in the Westinghouse letter dated March 13, 2003 apply to the manual calculation method and do not apply to the method using WGOTHIC.

Additional Response (Revision 2)

1. There is one transient type that challenges the minimum service metal temperature requirement of -18.5 F. These transients are an inadvertent actuation of the active containment cooling system (VCS). These transients are discussed in depth in RAI-TR09-008. Figure 1

depicts the inadvertent fan cooler operation case at the minimum safety analysis temperature of -40°F, and an additional case at -30 °F. The WGOTHIC computer code was used to analyze these transients. Figure1 shows the minimum service metal temperature for the inadvertent fan cooler case. The transient was completely contained in one case. The case was allowed to equilibrate for 35000s before transient initiation. Operator action is assumed to occur within 60 minutes to shut off the fan coolers and return the transient to normal conditions. Figure 2 depicts the inadvertent fan cooler case at -30°F. This case is evaluated for containment shell temperature because wind speed at -30°F ambient condition is recorded to be faster than at -40°F resulting in a higher velocity through the annulus between the containment and air baffle and therefore greater heat transfer. The increased heat transfer results in a lower shell temperature. For Figures 1 and 2 the minimum service metal temperature is 7.18°F for the -40°F case and -0.61°F for the -30°F case. The transient cases along with the entire spectrum of analyses considering the external pressure and minimum service metal temperature can be found in APP-MV50-Z0C-039 Rev. 0.

Figure 1: Inadvertent Fan Cooler Case at T = -40 F

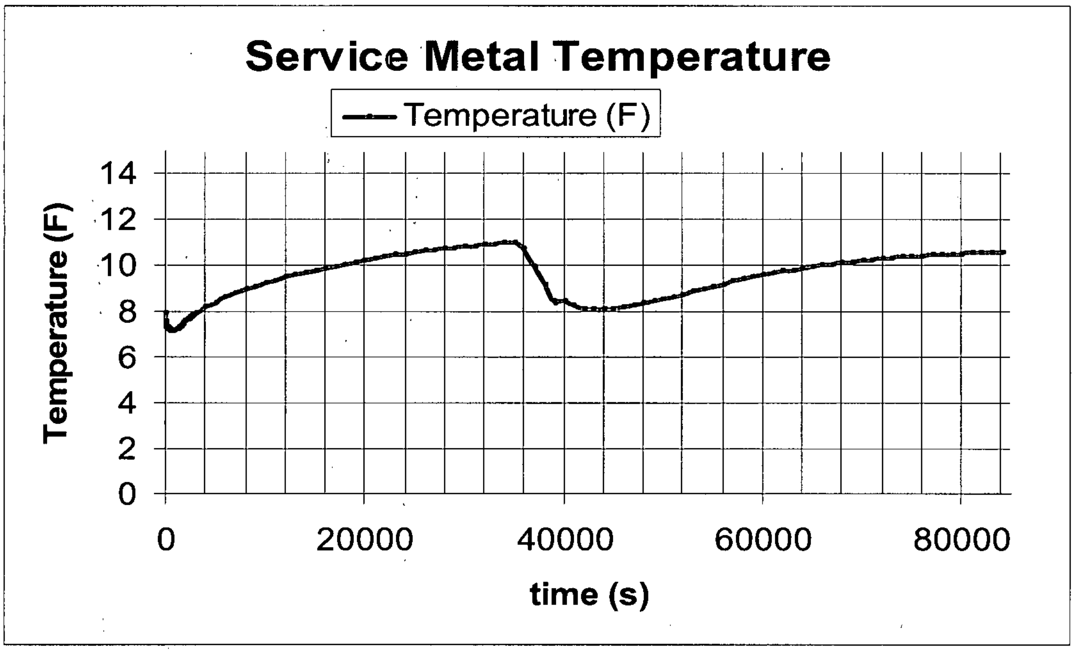
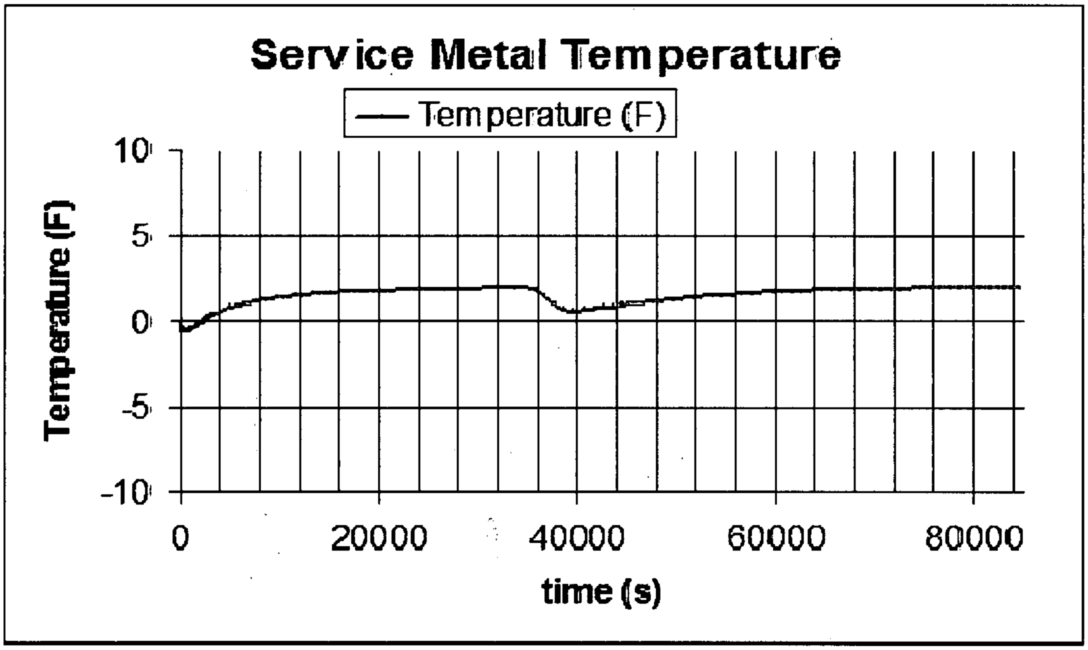


Figure 2: Inadvertent Fan Cooler Case at T= -30 F



Design Control Document (DCD) Revision: (Revision 0)

The following change will be incorporated in the next revision of the DCD: This change is superseded In RAI-TR09-008, Revision 4

- Note 6 will be added in DCD Table 3.8.2-1 as follows:

  The 'Lowest Service Metal Temperature' corresponding to -40 degree F outside temperature is -18.5 °F.

PRA Revision:
None

Technical Report (TR) Revision: (Revision 0)

Technical Report APP-GW-GLR-005 (TR 9) will be revised as follows:

Note 6 will be added in Table 3.8.2-1 and will read:

The 'Lowest Service Metal Temperature' corresponding to -40 degree F outside temperature is -18.5 degree F.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP-3.8.2-SEB1-03
Revision: 1

Question: (Revision 0)

Table 3.8.2-1 of DCD Rev. 16, which provides the load combinations and service limits for the steel containment vessel, has been revised. Westinghouse is requested to explain the following items:

1. Why were other load combinations identified in NUREG-0800, SRP 3.8.2, Acceptance Criteria and Regulatory Guide 1.57, Rev. 1, omitted? (e.g., SRP 3.8.2 II.3.B.iii.(1)(a); II.3.B.iii.(3)(b), (d), and (e); and II.3.B.iii.(5) for post flooding condition). Please provide the bases for omitting the load combinations and reference any necessary documents to support this action.

2. A new load combination has been added in the DCD for Service Levels A and D, which includes the external pressure of 0.9 psid. Westinghouse is requested to provide the technical basis for this pressure load and provide the corresponding temperature value and the basis for this temperature.

   Clarify in the DCD what is meant by "loss of all AC in cold weather" used in Footnotes 3 and 5.

3. Although load combinations with OBE are not required because the OBE is defined as less than or equal to 1/3 of the SSE, there is no indication that the OBE loading is considered in the appropriate load combinations for fatigue as described in SRP 3.8.2 acceptance criterion - II.3.B.iii.(2).

If your response to this request for additional information will reference Revision 17 to the AP1000 DCD, please provide an exact reference.

Additional Question (Revision 1)

Confirm that several additional load combinations identified in the RAI were considered in the design of the containment. During a conversation with the NRC load combinations of interest were identified.

Westinghouse Response:

1. The containment vessel (CV) design has gone through a detailed review by the NRC staff and consultants. This review included the load combinations and service limits for the containment vessel.

In the most recent Technical Audit meeting in Pittsburgh (held the week ending 5/23/2008), the CV design as described in the DCD Revision 16, and the CV design report and calculations related to Technical Report 9 (TR-09) (Reference 1) were reviewed in great detail. The CV design calculations include the various design load combinations. The governing combinations are present in DCD Rev. 16 Table 3.8.2-1, "Load Combinations and Service Limits for Containment Vessel." This table was revised in TR-09 and included in this review.

The post flooding condition load combination was also discussed in the May 2008 NRC audit. In response to the revised request, RAI-TR09-005 Rev 2 was sent to the NRC in September 2008 (Reference 2). The following response is provided again:

The post accident flooding load combination is not applicable in the design of the containment vessel. Containment flooding events are described in DCD subsection 3.4.1.2.2.1. Curbs are provided around openings through the maintenance floor at elevation 107'-2" to control flooding into the lower compartments. The maximum curb elevation of 110'-2" establishes the maximum flooding on the containment vessel boundary. There are seals at elevation 107'-2" between the containment vessel and maintenance floor as shown in sheet 2 of DCD Figure 3.8.2-8. In the event of seal leakage hydrostatic pressure could be imposed on the vessel behind the concrete.
Pressure loads below elevation 100' are resisted by the mass concrete of the nuclear island basemat. Pressure loads above elevation 100' would be carried by the steel vessel. Hence, there could be a maximum hydrostatic head of 10' corresponding to a hydrostatic pressure of about 5 psi.

The containment vessel is designed for a design pressure of 59 psi. This pressure exceeds the maximum calculated pressure in design basis accidents.

Maximum flooding occurs late during the accident transient. The combination of hydrostatic pressure at elevation 100' and containment pressure is less than the design pressure of 59 psi. Hence, the post-LOCA flooding event is enveloped by the other design cases.

2. This load combination corresponds to an external pressure based on an evaluation of a credible initiating event in cold weather ~~postulated scenario of 'inadvertent actuation of the fan coolers with -40 degree F outside temperature'.~~

   Several possible credible initiating events were evaluated in order to verify this external pressure. See the response to RAI –TR09-008, Rev. 4 for more information on these scenarios.
   ~~With the environment temperature assumed to be -40 degree F, the containment operating temperature was calculated to be 69 degree F assuming no fan cooler operation. The maximum credible cooldown transient at the limiting cold conditions was assumed to be inadvertent activation of the fan coolers. The resulting pressure difference was calculated to be -0.9 psid.~~

The scenario corresponding to this load combination was reviewed by the NRC staff and the NRC consultant. It was agreed to call this condition as 'inadvertent actuation of AC during cold weather'. This change was incorporated in TR-09 and DCD Revision 17. The vessel was evaluated for potential buckling due to corresponding external pressure of 0.9 psi.

(Note: For this case, the abbreviation AC refers to the VCS containment air cooling system.)

3. ASME Section III, Division 1, Subsection NE, Paragraph NE-3221.5 provides the requirements for analysis for cyclic operation. Paragraph NE-3221.5(d) 'Vessels Not Requiring Analysis for Cyclic Service' provides a list of six conditions that if the specified Service Loadings of the vessel or portion thereof meet all six conditions, an analysis for cyclic service is not required.

   Westinghouse has a calculation, available for audit, to show how these six conditions are met.

Westinghouse Response to Revision 1:

The containment vessel is protected from the direct effects of wind//tornado loads (and associated potential missiles) by virtue of its location inside the shield building. The differential pressure effects of a tornado are also reduced because of the location; and are bounded by other pressure loadings for which the containment vessel is designed.

Westinghouse confirms that, as shown in DCD Table 3.8.2-1, the Containment Vessel shell is designed for the Tornado (W_t) and Wind (W) loads.

In the following specific load combinations for which the NRC reviewer requested information are addressed. The load combinations identified in the Design Control Document (DCD) in support of the Design Certification Amendment are not changed from the Certified Design.

1. SRP 3.8.2 II.3.B.iii.(1)(a)
   Normal operating plant condition

   $D + L + T_o + R_o + P_o$

   Response: This load combination calls for P_o, which is "External pressure loads resulting from pressure variation either inside or outside containment." For the AP1000 CV this results in an external pressure, "based on evaluation of credible initiating event in cold weather." Please note that the terms use in the DCD used for the load combinations are slightly different that the NRC guidance. Westinghouse uses P_e for external pressure.

2. SRP 3.8.2 II.3.B.iii.(3)(b)
   Operating plant condition in combination with SSE

   $D + L + T_o + R_o + P_o + E'$

   Response: This load combination is included in the AP1000 Design Control Document (DCD) and the containment design specification. It is captured as a Service Level D Service Limit load combination in DCD Table 3.8.2-1. The application of Service Level D limits to this load combination was included in the DCD Revision 15 that is referenced by the AP1000 Design Certification. Westinghouse has not changed this load combination or how it is applied to the containment vessel in the DCD that supports the design certification amendment. The NRC approval of the application of Service Level D limits to this load combination it documented in the AP1000 FSER (NUREG-1793) as follows:

   In addition to the four issues discussed above, the staff requested the applicant to provide the technical basis for using Service Level D allowable stress, instead of Service Level C allowable stress, for the load combination of seismic loads plus design external pressure when the evaluation of the containment vessel adequacy was performed. During the audit conducted on October 6–9, 2003, the applicant presented an evaluation based on the load combination, assuming that these two events occur simultaneously. In its submittal dated December 12, 2003 (Revision 3 of the response to Open Item 3.8.2.1-1), the applicant provided a final calculation that justifies the change of design basis from Service Level C to Service Level D. Based on its review of these documents and the discussion with the applicant, the staff found that the change from Service Level C to Service Level D for the load combination of seismic plus design external pressure is technically justified because of the extremely low sequence frequency (less than 1E-10 per year) leading to containment failure.

3. SRP 3.8.2 II.3.B.iii.(3)(d)
   Deal Dead load plus pressure resulting from an accident that releases hydrogen generated from 100-percent fuel clad metal-water reaction accompanied by hydrogen burning

   $D + P_{g1} + P_{g2}$

   Response: The AP1000 addresses the production of large quantities of hydrogen from the oxidation of zirconium and other metals as a result of a postulated severe accident. The AP1000 includes hydrogen igniters inside containment to assure that hydrogen generated in a severe accident is burned prior to reaching an explosive mixture. The discussion of the generation and burning of hydrogen as a result of a severe accident is included in DCD Subsection 19.41.

The containment is also evaluated for the deterministic severe accident pressure capacity. This evaluation is discussed in DCD Subsection 3.8.2.4.2 "Evaluation of Ultimate Capacity". According to 10 CFR 50.34(f), the peak LOCA pressure plus the peak pressure from a hydrogen burn must be less than ASME Service Level C (not including buckling). The Service Level C maximum capacity is 117 psig at 300°F as presented in DCD section 3.8.2.4.2.8. The peak pressure from the hydrogen burn (Pg1 + Pg2) is 90.3 psig) as reported in Section 41.11 and Table 41-4 of the PRA report. The severe accident conditions are beyond design basis accidents and the load combinations for these severe accident evaluations are not included in the load combinations and service limits for the containment vessel provided in the DCD.

The containment ultimate capacity and the treatment of severe accidents that result in the generation of hydrogen is not altered from what was included in the AP1000 certified design. In the Final Safety Evaluation Report for AP1000 (NUREG-1793) the NRC states the following.

> "The staff considers the analysis procedures used in evaluating the ultimate capacity of the AP1000 containment to be consistent with sound engineering practice for such evaluations. On this basis, the staff concludes that the results of the AP1000 ultimate capacity evaluation constitute acceptable input for probabilistic risk assessment analyses and severe accident evaluations."

4. SRP 3.8.2 II.3.B.iii.(3)(e)

   $D + P_{g1} + P_{g3}$

   Response: The AP1000 does not have a post accident inerting system. Therefore, this load combination is not applicable to the AP1000.

5. SRP 3.8.2 II.3.B.iii.(5)
   Post Flooding Condition

   Response: <u>This condition was previously addressed in the Response to Rev. 1.</u>

References:

1. APP-GW-GLR-005, Revision 1, "Containment Vessel Design Adjacent to Large Penetrations," Technical Report Number 9, submitted with DCP/NRC1988, September 5, 2007.

2. Letter, Sisk (Westinghouse) to NRC, "AP1000 Response to Request for Additional Information (TR09)", DCP/NRC2261, September 15, 2008.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None