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December 14, 2009

Subject: AP1000 Response to Request for Additional Information (SRP 6)

Westinghouse is submitting a response to the NRC request for additional information (RAI) on SRP Section 6. 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-SRP6.2.1.1-SPCV-07 R2

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,

Robert Sisk, Manager
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/Enclosure

1. Response to Request for Additional Information on SRP Section 6

D063
NRO

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ENCLOSURE 1

Response to Request for Additional Information on SRP Section 6

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP6.2.1.1-SPCV-07
Revision: 2

Question: (Revision 0)

RAI SRP6.2.1.1-SPCV-01 through -04 requested additional information on the change to the maximum external pressure analyses. Westinghouse referenced calculation notes APP-MV50-Z0C-020, Rev. 0 in their response. The following issues remain regarding this analysis and the RAI responses:

a) In response to RAI SRP 6.2.1.1-SPCV-01, Westinghouse stated that while the accident analysis biased the heat transfer coefficients low, the external pressure analysis used nominal heat transfer coefficients. Provide details on how the nominal heat transfer coefficients used in the external pressure analysis differ from those described in the accident analysis documented in WCAP-15846.

b) Westinghouse assumed that the heat loss at operating reactor power was equal to the maximum capacity of the fan coolers, or 26167 Btu/s. Justify why this approach results in a bounding value for heat loss. Clarify why Appendix B and D of the referenced calc-notes list heat rates of 2536.33 Btu/s rather than the stated 26167 Btu/s for both the heater and cooler. Provide the value actually used in the WGOTHIC model.

c) There is a 10x difference in time scale between DCD Figure 6.2.1.1-11 and the associated data points from Appendix E of the referenced calc notes. Please resolve the discrepancy. If the scale in the DCD Figure is correct, justify why analysis ended after 6 minutes.

d) In response to RAI-SRP6.2.1.1-SPCV-01 and -03, Westinghouse provided values calculated by WGOTHIC for the heat transfer coefficients of the containment shell, baffle, and shield building. Explain how these were derived (specific time point and WGOTHIC conductor) and why they differ from the heat transfer coefficients reported in the referenced calc notes (where at 3600 sec, h-outside containment shell =5.2 B/hr-ft^2-°F and h-inside containment shell =1.6 B/hr-ft^2-°F).

e) Although the referenced calc-notes state that the containment shell temperature was initially set to -18°F for the second part of the analysis (actuation of fan coolers after steady state operation at low temperature), the WGOTHIC model included in the Appendix has the shell conductors set to 69°F. Please provide a plot of the containment shell temperature versus time for this transient.

f) In response to RAI SRP 6.2.1.1-SPCV-04, Westinghouse states that the changes to the shield building air inlets make the air velocity in the annulus less dependent on external wind speed. In the original design, the assumed 48 mph wind speed was modeled with a 25 mph annulus velocity. For the new shield building design, describe how annulus velocity was modeled and how this correlates to a 48 mph wind speed.

Additional Question: (Revision 1)

a) The revised external pressure analysis consists of two steps - for the first step (steady state operation at cold conditions) it is conservative to assume *minimum* heat transfer to the environment while for the second step (inadvertant cooling transient) it is conservative to assume *maximum* heat transfer to the environment. However, the analysis assumptions (which were applied to both steps) were biased for maximum heat transfer to the environment (i.e. relative humidity of 100% and maximum condensation heat transfer coefficients). What sensitivity studies were performed on these parameters to demonstrate they are bounding?

b) The steady state portion of this analysis is not realistic, as the resultant pressure is well below the containment pressure Limiting Condition of Operation of -0.2 psig. When pressure exceeds the lower bound of Tech Spec B.3.6.4, how does operator restore the pressure and why is it conservative to neglect this action in the analysis?

c) How is it demonstrated that inadvertant actuation of active containment cooling on an extremely cold day produces the limiting event with respect to external pressure? What other events were evaluated and found to be less limiting?

d) Because the fan efficiency increases with temperature, it could potentially remove more heat from containment on a hot day than the heat removed via the shell on a cold day. What is the impact of external temperature on the calculated minimum internal pressure?

Additional Question: (Revision 2)

1) In the proposed DCD changes, the bounding external pressure event is identified as a nonmechanistic step change in containment atmosphere from 120F with 100% relative humidity to 50F, with an associated bounding pressure change is -2.9 psid. This is a change from both the event certified in rev. 15 and event described in rev. 17.
   a) Because minimum containment pressure is not a tech spec requirement, explain how it was determined to be 50F and how this will be controlled.
   b) What methodology (hand calcs, WGOTHIC) was used to calculate the bounding pressure change?
   c) What assumptions were made in analysis?
   d) Why is loss of ac power, which was certified to be limiting event in rev. 15, no longer the limiting event? (What changed in design or analysis to make this new event more limiting?)
   e) I would like to audit analysis.

2) Response to part a) states that best estimates are appropriate for this analysis, but the analysis never characterized the values as best estimates. Please explain how the values chosen for relative humidity and heat transfer options represent best estimates.

3) Response to part c) states that inadvertant actuation of the fan cooler is the only conceivable event to reduce internal pressure because inadvertantly actuation of spray system is not feasible and inadvertant actuation of the PCS would actually heat the shell on extremely cold day. Address why the other conditions discussed in tech spec basis B 3.6.5 are not limiting, including loss of ac power. Explain why a nonmechanistic step change to 50F was not considered to be limiting.

4) My interpretation of the response to part d) is that there are two external pressure values. One is -.9 psid, and this only applies to extremely cold days. The other is -2.9 psid, and this applies to every condition except for extremely cold days. I am confused as to what determines an extremely cold day. For example, what pressure value should be used at -30F? What about 0F?

Westinghouse Response (Revision 2):

Section 6.2.1.1.4 of the DCD is being revised to return the text that was included in Revision 15 of the DCD. The questions above and the previous responses are largely obviated by the change. The questions above are largely about sensitivity studies that support information that is to be included in DCD Subsection 3.8.2. RAI-TR09-008, Revision 4 provides more information about these sensitivity studies and addresses these questions.

The description of the external pressure condition described in 6.2.1.1.4 explains how the 2.9 psi design external pressure is determined to be bounding. The 2.9 psi design external pressure value is determined by structural capacity of the containment vessel and was included in Revision 15 of the DCD that supported the AP1000 design certification. The containment pressure and temperature transient scenario described is a bounding, non-mechanistic set of assumptions. The scenario is nonmechanistic because the initial 120 °F containment temperature is inconsistent with a coincident external ambient temperature of -40°F. The description in 6.2.1.1.4 is supported by a calculation and has been verified for the design certification amendment. The result of the calculation is that the bounding assumptions result in an external pressure differential less than the design external pressure.

The design external pressure (2.9 psi) is used in a design condition load combination that does not include seismic or thermal loads. Since thermal loads are not included in this design condition load combination the most limiting coincidence of thermal and pressure loads does not need to be determined.

The load combinations that evaluate extreme cold weather conditions include a thermal load and are identified in Section 3.8.2 as loads combinations evaluated for Service Level A and Service Level D limits. The Service Level D load combination also includes seismic loads. The development of the Service Level A and D load combinations is discussed in DCD Section 3.8.2. The loads for these combinations are based on more credible temperature and event initiation scenarios. Multiple different events at various external temperature conditions are evaluated to determine the appropriate pressure and thermal load combinations.

The DCD mark-up shown below is based on Revision 15 of Section 6.2.1.1.4. For the changes to DCD Section 3.8.2 please see the Revision 4 response to RAI-TR09-008.

The previous responses to the Revision 0 and 1 questions in this RAI are deleted as shown below.

Westinghouse Response (Revision 0):

a) The analyses described in WCAP-15846 are performed to calculate the passive containment pressure response to loss-of-coolant accidents and main steam line breaks. In these accident sequences, there is a large mass and energy release to the containment, the PCS water is actuated, and evaporative cooling is credited on the outside of the PCS shell. Lower bounded heat and mass transfer coefficients are used to calculate a conservatively high peak pressure for the containment design analyses. Upper bounded heat and mass transfer coefficients are used to calculate a conservatively low containment back pressure for the ECCS evaluation model.

The external pressure analysis for the passive plant is analogous to an inadvertent containment cooling actuation analysis in a conventional nuclear plant containment building. The passive containment does not have an internal containment spray system that can be spuriously actuated. Therefore, the limiting sequence for the external pressure analysis is the inadvertent actuation of the containment cooling system fan cooler at the coldest environmental conditions.

Natural convection heat transfer with condensation is the principal method of energy exchange to the inside surface of the containment shell. For the peak pressure containment analyses described in WCAP-15846, it is conservative to calculate lower bounded heat and mass transfer to the external shell. The McAdams turbulent free convection correlation, with a lower bounding multiplier value of 0.73, is used to calculate the condensation heat and mass transfer rate to the inside surface of the containment shell in the peak pressure analysis. For the external pressure analysis, it is conservative to calculate a lower internal pressure. The containment atmosphere is assumed to have an initial relative humidity of 100%; the pressure will decrease as water vapor in the air is condensed on the shell and fan cooler coils.

The WGOTHIC DIRECT heat transfer coefficient option, with the condensation option set to MAX, is used to calculate the heat and mass transfer rates to the inside and outside surfaces of the containment shell in both the steady-state and transient phases of the external pressure analysis. The DIRECT option uses the McAdams turbulent free convection correlation. The MAX condensation option uses the maximum value between the Uchida and Gido-Koestel condensation correlations.

b) The response to RAI-SRP6.2.1.1-SPCV-01 was reviewed along with the input values discussed in calculation APP-MV50-Z0C-020, Rev. 0. The value of 26,167 Btu/sec for the heat load at operating reactor power quoted in the RAI responses is in error. The actual value for the containment heat loads entered in WGOTHIC and used in calculation APP-MV50-Z0C-020 was 2536.33 BTU/s. As discussed below, this value is appropriate and conservative.

The containment heating and cooling calculation APP-VCS-M3C-001 Rev. B was reviewed to estimate the value of the containment heat load and compare it with the value used in APP-MV50-Z0C-020. APP-VCS-M3C-001 Rev. B provides an estimate of the containment heat loads on a room-by-room basis to size the containment cooling system. The containment cooling system is sized to provide 15% margin to the total containment heat loads and takes credit for passive heat removal through the shell on a summer day, assuming the peak ambient temperature of 115°F.

Therefore, the containment heat load can be estimated as:

Total heat-removal capacity of the fan coolers	8.82 MBtu/hr
Heat removed through shell	+0.67 MBtu/hr
15% margin added to fan-cooler capacity	-1.42 MBtu/hr
Heat load to the containment	8.07MBtu/hr
	= 2242 Btu/sec

The maximum initial containment temperature provides the limiting condition for the peak external pressure. Therefore, the heat load used in the steady-state WGOTHIC analysis in APP-MV50-Z0C-020 to calculate the initial containment conditions is conservative.

For the transient analysis, calculation APP-MV50-Z0C-020 assumed a maximum fan-cooler capacity of 2536.33 Btu/sec. The maximum fan-cooler heat-removal capacity from APP-VCS-M3C-001 is 2450.6 Btu/sec (8.82 MBtu/hr). The larger fan-cooler heat-removal value is limiting for the peak external pressure; therefore the value of 2,536.33 Btu/sec used in calculation APP-MV50-Z0C-020 is conservative. The fan-cooler heat removal is assumed to be a linear function of the containment temperature, with the maximum heat-removal rate at 120°F and 0 Btu/sec heat removal rate at 32°F. The actual minimum temperature of the chilled water is 40°F (from APP-VWS-M3-001, Rev. B), so the fan-cooler heat-removal rate used for the calculation in APP-MV50-Z0C-020 is conservative.

For the transient calculation, a lower containment heat loading is conservative for the external peak pressure. The heat load to the containment for the transient calculation is the containment heat load of 2242 Btu/sec plus the heat load from the fan-cooler motors, which is 1.02 MBtu/hr or 283 Btu/sec. The total containment heat load based on

APP-VCS-M3C-001 is 2525 Btu/sec, which is within 1% of the value (2536 Btu/sec) assumed in calculation APP-MV50-Z0C-020.

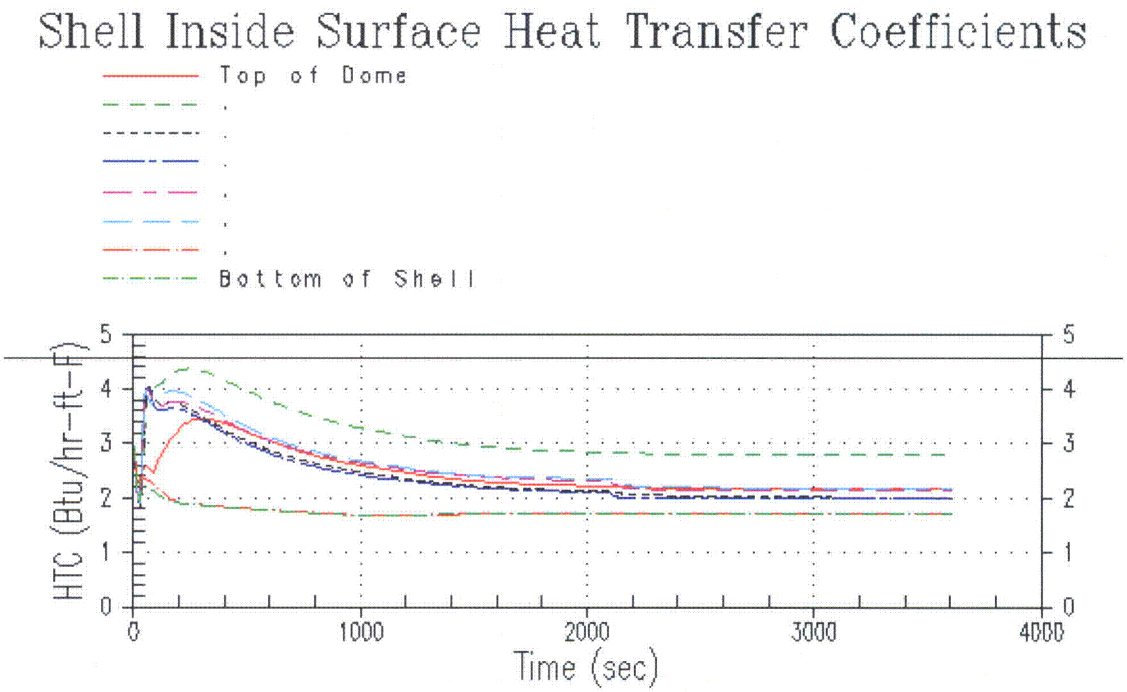
Therefore, the heat loads and fan-cooler heat capacity presented in APP-MV50-Z0C-020, Rev. 0 are appropriate and conservative for the peak external pressure calculation.

c) The DCD figure 6.2.1.1-11 time scale is in error and should be corrected. See DCD revisions section below.

d) The heat-transfer coefficients provided in the RAI responses were taken from different thermal conductors than the heat-transfer coefficients plotted in the calcnote. The heat transfer coefficients calculated by WGOTHIC for one "stack" of shell thermal conductors (PCS shell from the dome to the operating deck) from the steady-state run are presented in Table D-1. The heat transfer coefficients calculated by WGOTHIC for one stack during the transient are provided in Figures D-1 and D-2.

Table D-1
Heat Transfer Coefficients from the Steady State Run

Location	Inside HTC Btu/hr-ft^2-°F	Outside HTC Btu/hr-ft^2-°F
Top of Dome	1.8	1.1
-	3.5	4.5
-	2.8	7.4
-	2.9	7.8
-	3.4	7.8
-	1.9	7.7
-	1.6	7.7
Bottom of Shell	1.6	5.1


Shell Inside Surface Heat Transfer Coefficients
Top of Dome
Bottom of Shell
HTC (Btu/hr-ft-F)
Time (sec)
0
1
2
3
4
5
0
1000
2000
3000
4000

~~Figure D-1~~

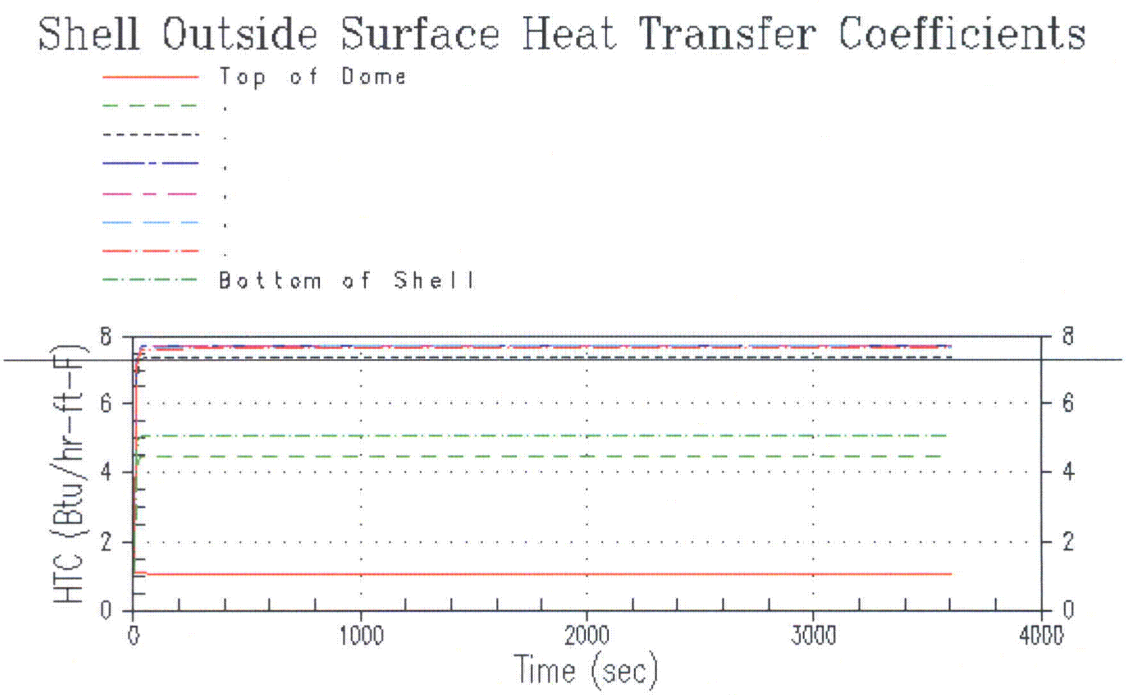


Figure D-2

e) The containment shell initial temperatures were appropriately set to -18°F in the transient WGOTHIC run of APP-MV50-Z0C-020. The initial temperature was determined from a conservative estimate of the average temperature of the shell in the steady-state run. The temperature response of one PCS "stack" during the transient is provided in Figure E-1.

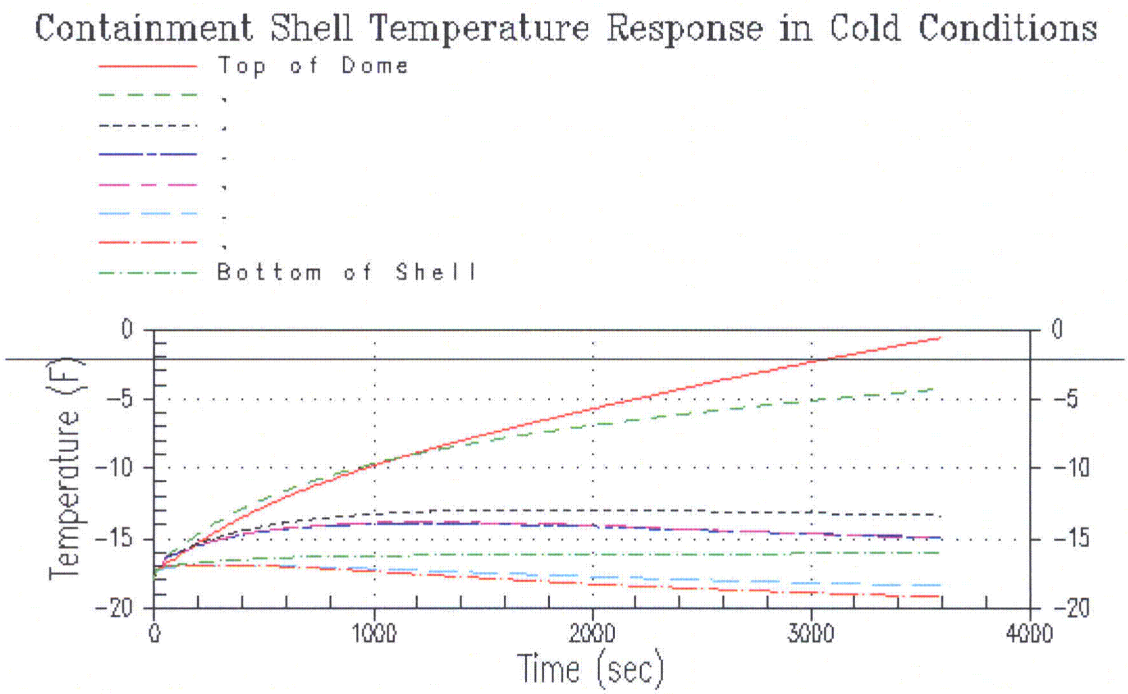
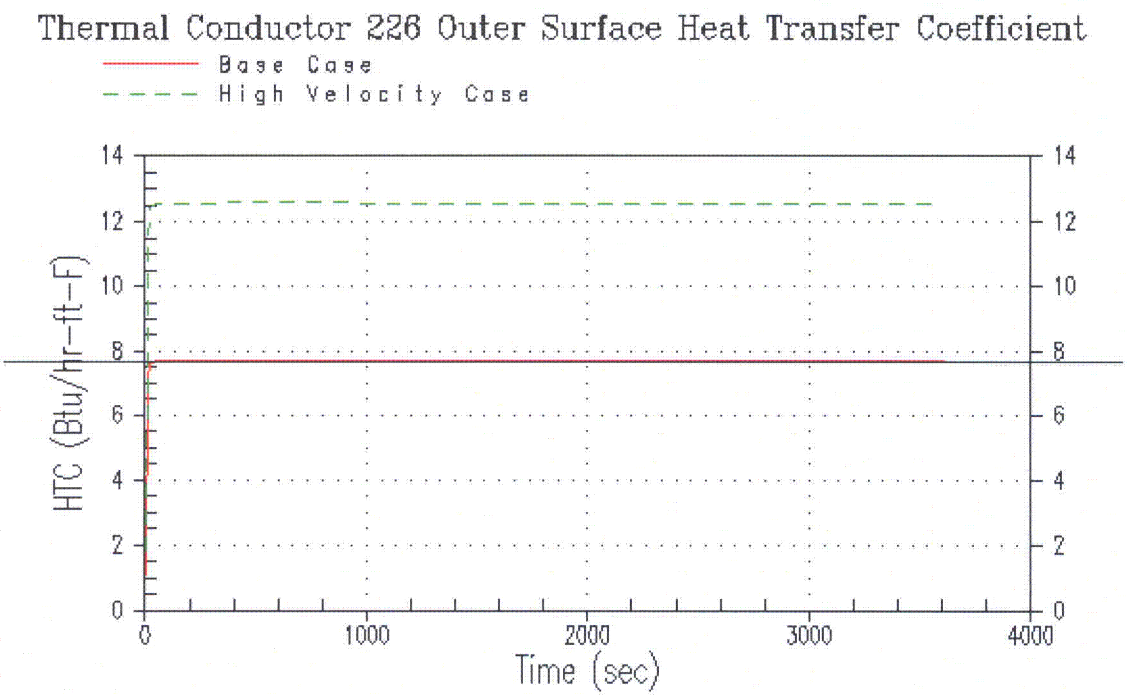


Figure E-1

f) The wind-induced annulus velocity does not have a significant impact on the calculation with respect to the annulus velocity induced by the gas-density difference in the PCS. In the APP-MV50-Z0C-020 analysis, WGOTHIC calculates the velocity through the annulus, which is 25 ft/s (17 mph), based on density differences. A sensitivity analysis was run increasing the heat-transfer coefficients in the PCS annulus by 1.62 in the transient pressure case. The Nussult number is a function of the velocity (Reynold's number) raised to the 0.8 power, so the resulting heat-transfer coefficient corresponds to an annulus velocity of 36.8 ft/s (25 mph). The WGOTHIC heat-transfer coefficients on the outer shell surface increase as shown in Figure F-1. The impact on the peak external pressure is 0.024 psi (Figure F-2), which is a 3% increase in the external pressure.



Thermal Conductor 226 Outer Surface Heat Transfer Coefficient
Base Case
High Velocity Case
HTC (Btu/hr-ft-F)
Time (sec)
0
1000
2000
3000
4000
0
2
4
6
8
10
12
14

~~Figure F-1~~

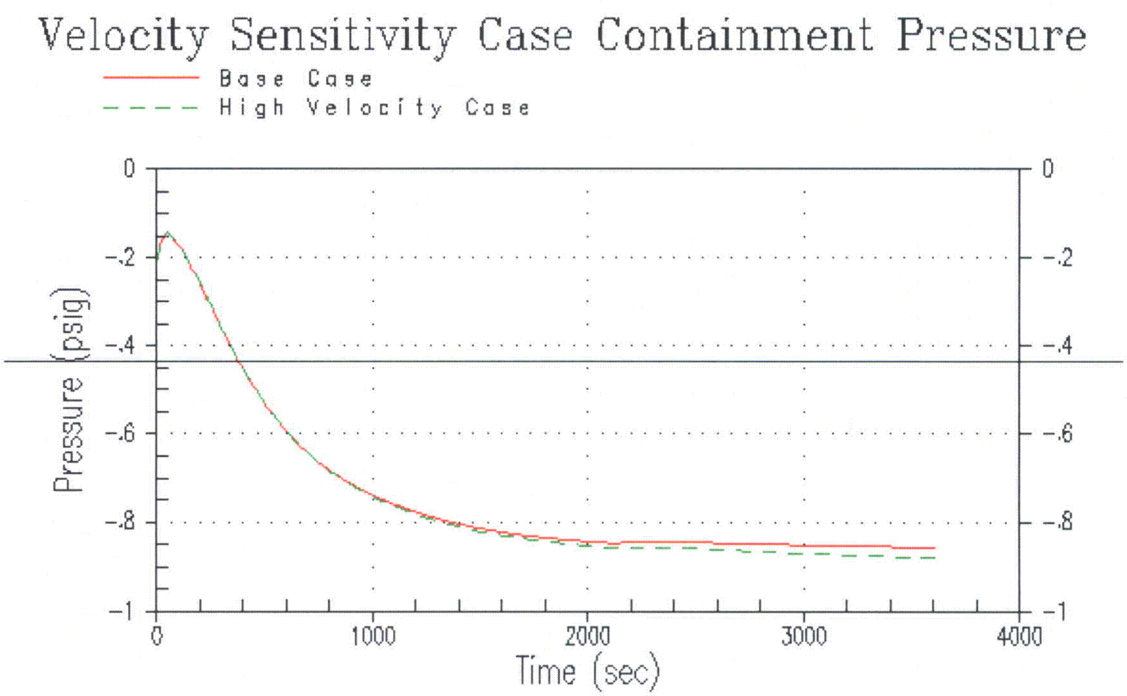


Figure F-2

Westinghouse Additional Response: (Revision 1)

The information provide in DCD Subsection 6.2.1.1.4 is intended to be used for the structural evaluation of the steel containment pressure vessel. It is not intended to be used for containment performance analysis. The responses below and the DCD revision are intended to clarify that.

a) The external pressure analysis is performed to provide for an extremely unlikely adverse load combination consisting of a safe-shutdown earthquake couple with an inadvertent actuation of the containment cooling system resulting in a maximum external pressure. In addition, this is postulated to occur at the lower bound of the operating temperature range of -40°F. This extremely unlikely sequence of events makes it unnecessary to apply the same type of assumptions used in the design basis pressure analysis in Chapter 6.2. For this analysis, best estimate assumptions are appropriate.

b) As addressed above, the purpose of the steady-state portion of the calculation is to determine the operating temperature of the containment for very cold external temperature, and to use these temperatures as the initial conditions to the transient cooldown calculation.

~~For this analysis, the containment isolation valves are assumed to be open so that there is no pressure difference across the containment shell.~~

~~In the second part of the calculation, the pressure is assumed to be initially at 14.5 psia to account for the instrument error.~~

~~c) Cooldown events from power are limited to the actuation of either the passive or active containment cooling system. As was described above, the actuation of the passive containment cooling system would result in the application of water at a temperature in excess of 40°F onto the containment shell which is far colder resulting in heating of the containment. The containment spray system cannot be inadvertently actuated since it is aligned for use only in the event of a severe accident. The only conceivable cooldown transient is the inadvertent actuation of the active fan cooler system.~~

~~d) External pressure evaluations were done using the bounding external pressure presented in Chapter 6.2 of -2.9 psid. This was considered excessively conservative for the load combinations assuming extremely cold conditions. This analysis applies only to these conditions.~~

Design Control Document (DCD) Revision:

Revision 2 of the response

The mark-up shows the changes to Section 6.2.1.1.4 and Figure 6.2.1.1-11 based on Revision 15 of the DCD.

6.2.1.1.4 External Pressure Analysis

Certain design basis events and credible inadvertent systems actuation have the potential to result in containment external pressure loads. Evaluations of these events show that a loss of all ac power sources during extreme cold ambient conditions has the potential for creating the worst-case external pressure load on the containment vessel. This event leads to a reduction in the internal containment heat loads from the reactor coolant system and other active components, thus resulting in a temperature reduction within the containment and an accompanying pressure reduction. Evaluations are performed to determine the design external pressure for which the containment is analyzed based on a postulated loss of all ac power sources.

The evaluations are performed with the assumption of a -40°F ambient temperature with a steady 48 mph wind blowing to maximize cooling of the containment vessel. The initial internal containment temperature is conservatively assumed to be 120°F, creating the largest possible temperature differential to maximize the heat removal rate through the containment vessel wall. A negative 0.2 psig initial containment pressure is used for this evaluation. A conservative maximum initial containment relative humidity of 100 percent is used to produce the greatest reduction in containment pressure due to the loss of steam partial pressure by condensation. It is also conservatively assumed that no air leakage occurs into the containment during the transient.

Evaluations are performed using WGOTHIC with conservatively low estimates of the containment heat loads and conservatively high heat removal through the containment vessel consistent with the limiting assumptions stated above. Results of these evaluations demonstrate that at one hour after the event the net external pressure is within the 2.9 psid design external pressure. This is sufficient time for operator action to prevent the containment pressure from dropping below the design external pressure, based on the PAM's containment pressure indications (four containment pressure instruments) and the ability to mitigate the pressure reduction by opening either set of containment ventilation purge isolation valves, which are powered by the 1E batteries.

The bounding containment pressure transient used to validate the design external pressure is shown in Figure 6.2.1.1-11.

See Subsection 3.8.2 for load combinations based on more credible combinations of events and temperature conditions used to evaluate Service Level A and D limits.

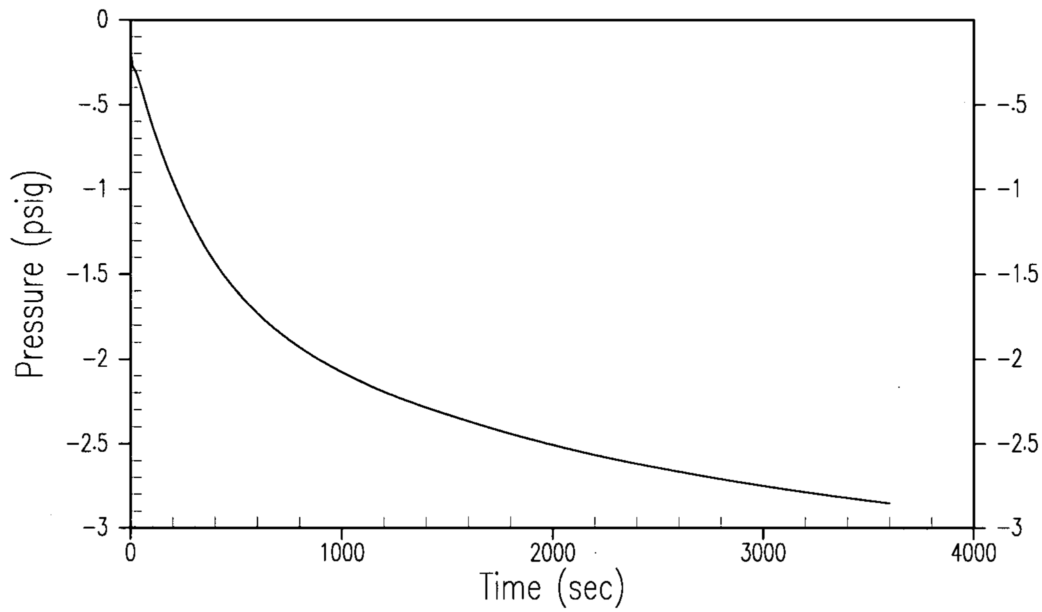
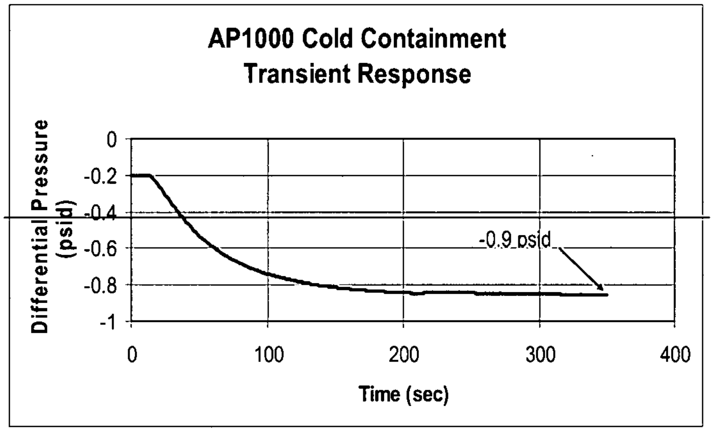


Figure 6.2.1.1-11

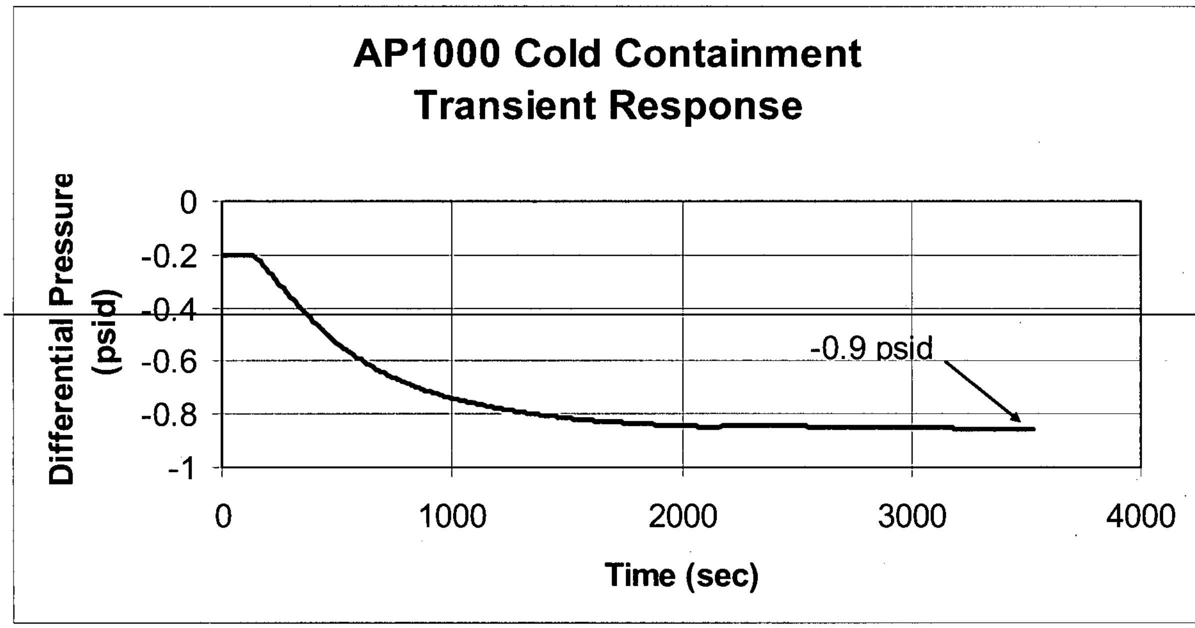
AP1000 Design External Pressure Analysis
Containment Pressure vs. Time

~~Revision 0 of Response~~

~~Replace the current DCD Rev. 17 Figure 6.2.1.1-11 (shown here)~~



~~With this version:~~



Revision 1 of Response

Revise Subsection 6.2.1.1.4 as follows:

6.2.1.1.4 External Pressure Analysis

Certain design basis events and credible inadvertent systems actuation have the potential to result in containment external pressure loads. The bounding external pressure can be calculated by assuming that the containment is operating at the maximum temperature, 120F, with 100% relative humidity, and experiences a step change to the minimum operating temperature, 50F. The calculated pressure change for this transient is -2.9 psid. It should be noted that this value is bounding and cannot be achieved through any mechanistic way.

A more realistic external pressure transient is the inadvertent actuation of the active and/or passive containment cooling system. This transient results in external pressures that are significantly less than the bounding value. The more realistic external containment pressure transient is shown in Figure 6.2.1.1-11.

These bounding and more realistic external pressure loading conditions are developed to evaluate the structural capability of the steel containment pressure vessel. These loading combinations are not included to evaluate the containment performance response.

PRA Revision: None

Technical Report (TR) Revision: None