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September 29, 2009

Subject: AP1000 Response to Requests for Additional Information on Containment Vessel External Pressure Analysis - RAI-SRP-3.8.6-SEB1-01 R1, RAI-SRP6.2.1.1-SPCV-07 R1, and RAI-TR09-008 R3

Westinghouse is submitting a response to NRC requests for additional information (RAI) on SRP Sections 3 and 6, and AP1000 Standard Combined License Technical Report 9, APP-GW-GLR-005, "Containment Vessel Design Adjacent to Large Penetrations." This combined response represents the remainder of information requested on the Containment Vessel External Pressure Analysis.

This 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-SRP-3.8.6-SEB1-01 R1
RAI-SRP6.2.1.1-SPCV-07 R1
RAI-TR09-008 R3

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
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Requests for Additional Information on SRP Sections 3 and 6, and Technical Report 9



D063
NRO

| | | | | |
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ENCLOSURE 1

Response to Requests for Additional Information on SRP Sections 3 and 6, and Technical Report 9

RAI Response Number: RAI-SRP6.2.1.1-SPCV-07
Revision: 1

***Question:***

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.

**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?

**Westinghouse Response:**

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 |

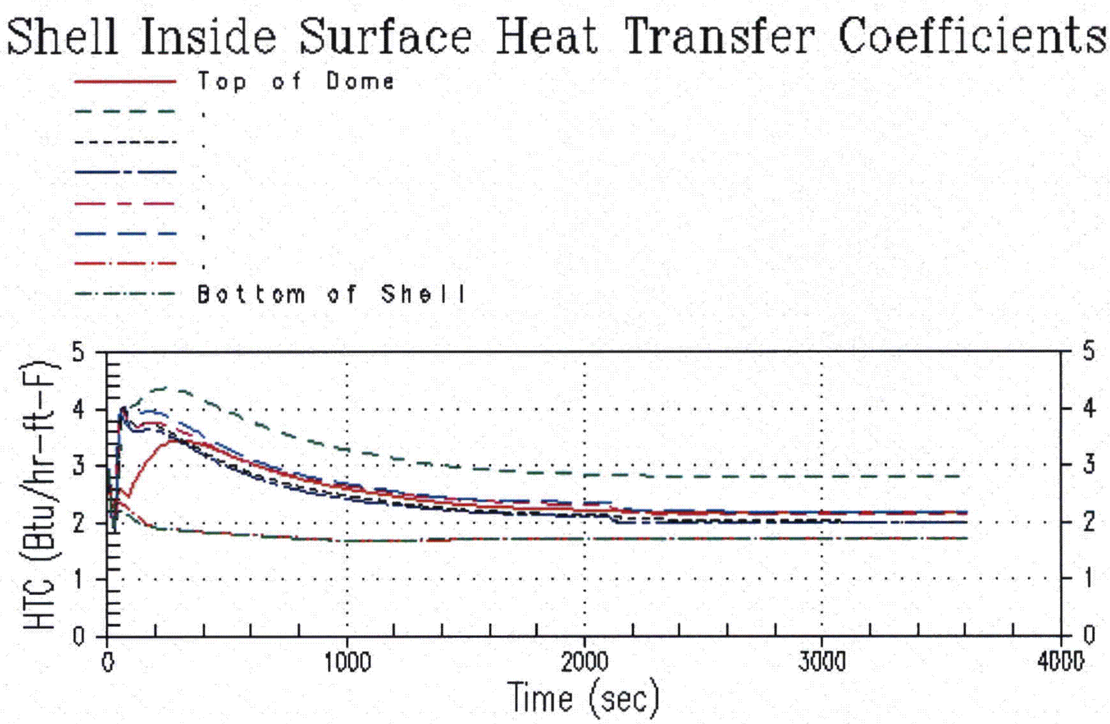



Figure D-1

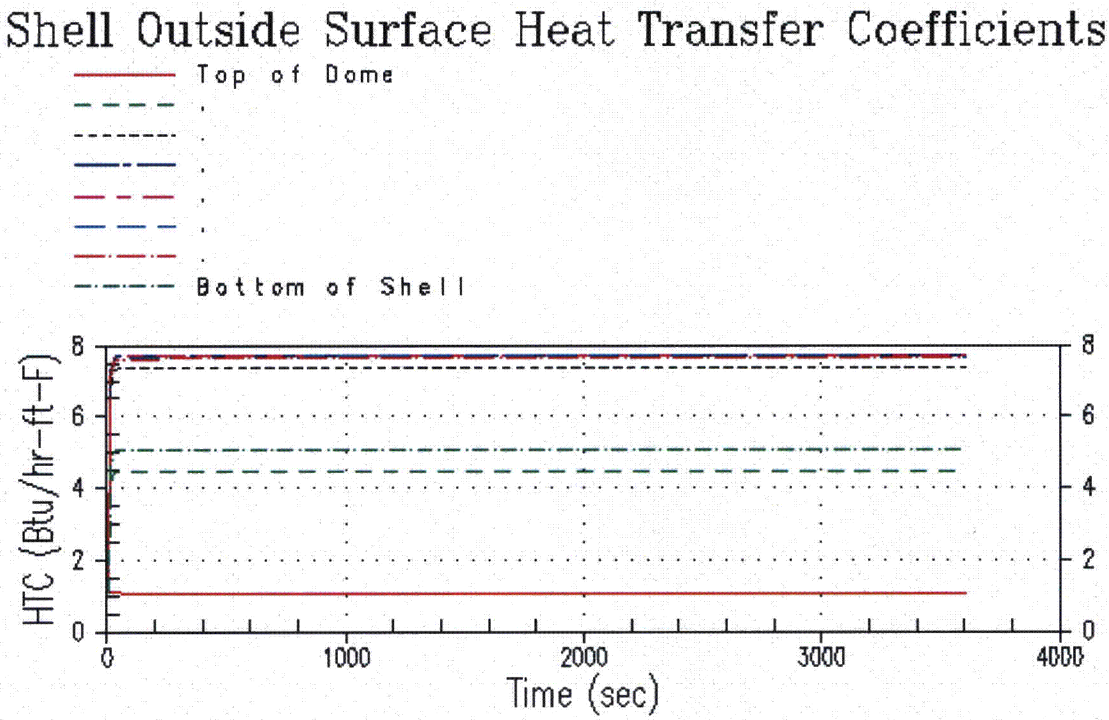

Shell Outside Surface Heat Transfer Coefficients
Top of Dome
Bottom of Shell
HTC (Btu/hr-ft-F)
Time (sec)
0
2
4
6
8
0
1000
2000
3000
4000

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.

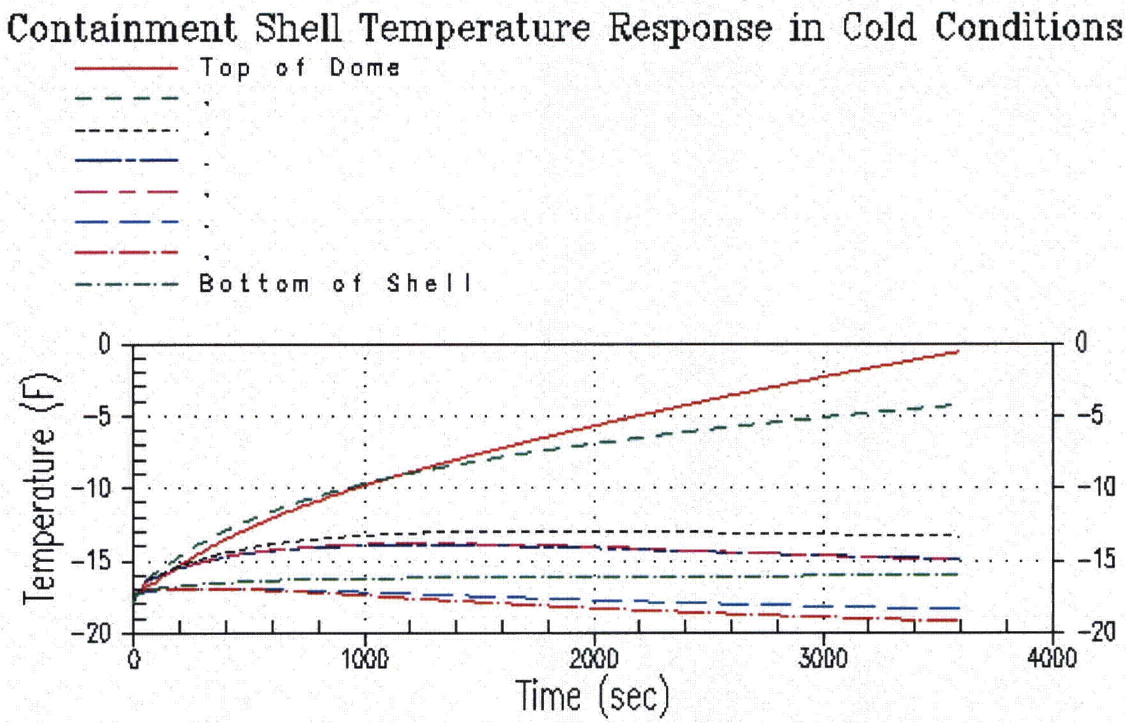



Figure E-1

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.

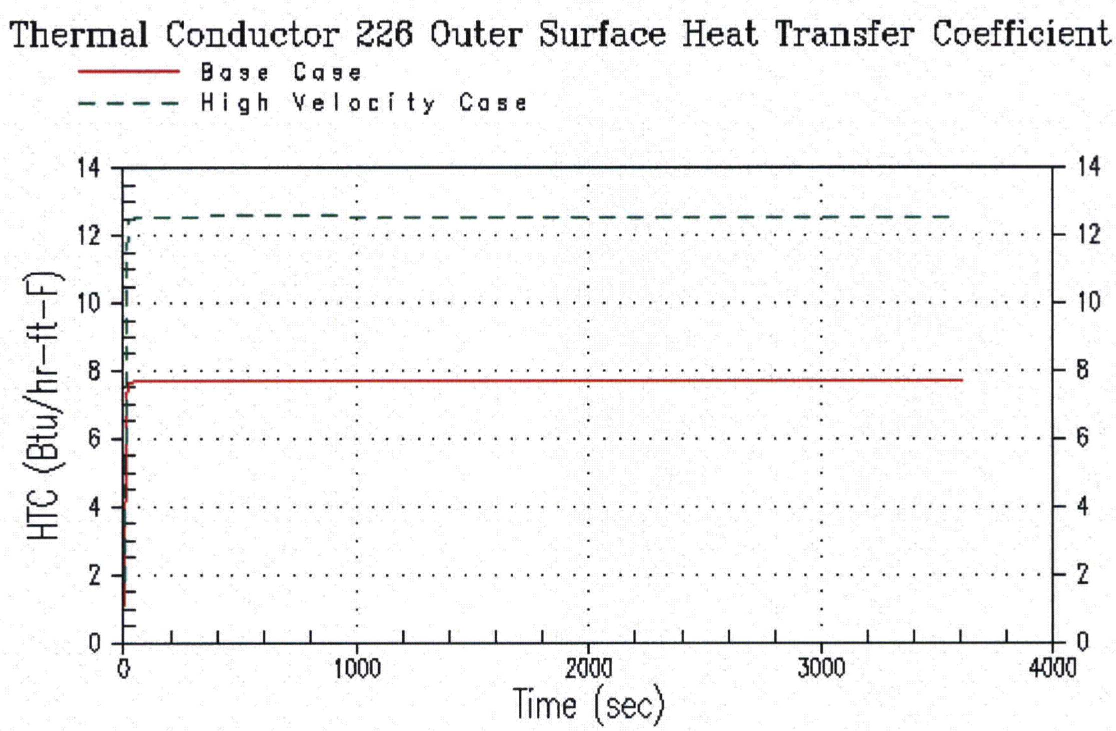



Figure F-1

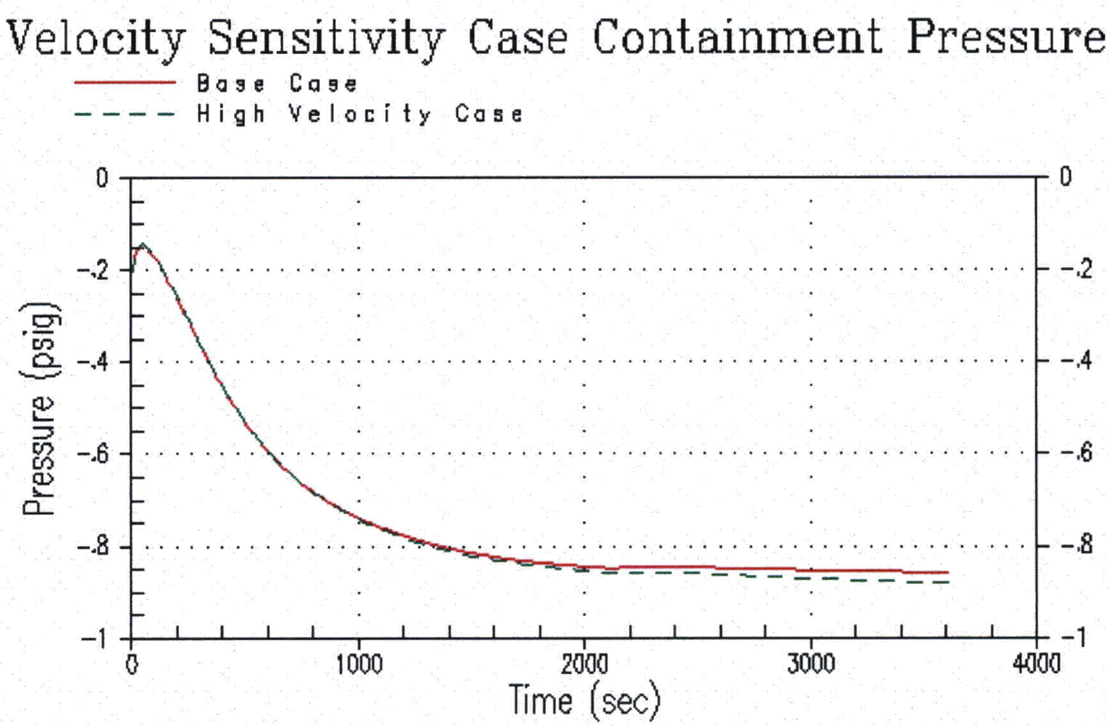



Figure F-2

**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.

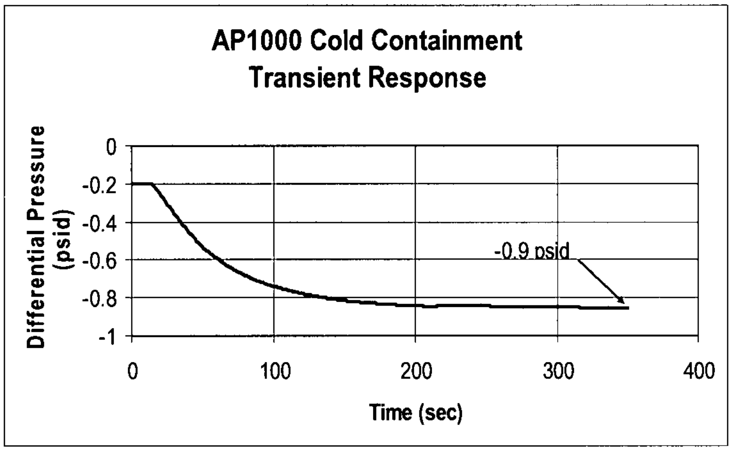
c) Cooldown events from power are limited to the actuation of either the passive or active containment cooling system. As was described above, the actuation of the passive containment cooling system would result in the application of water at a temperature in excess of 40°F onto the containment shell 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.

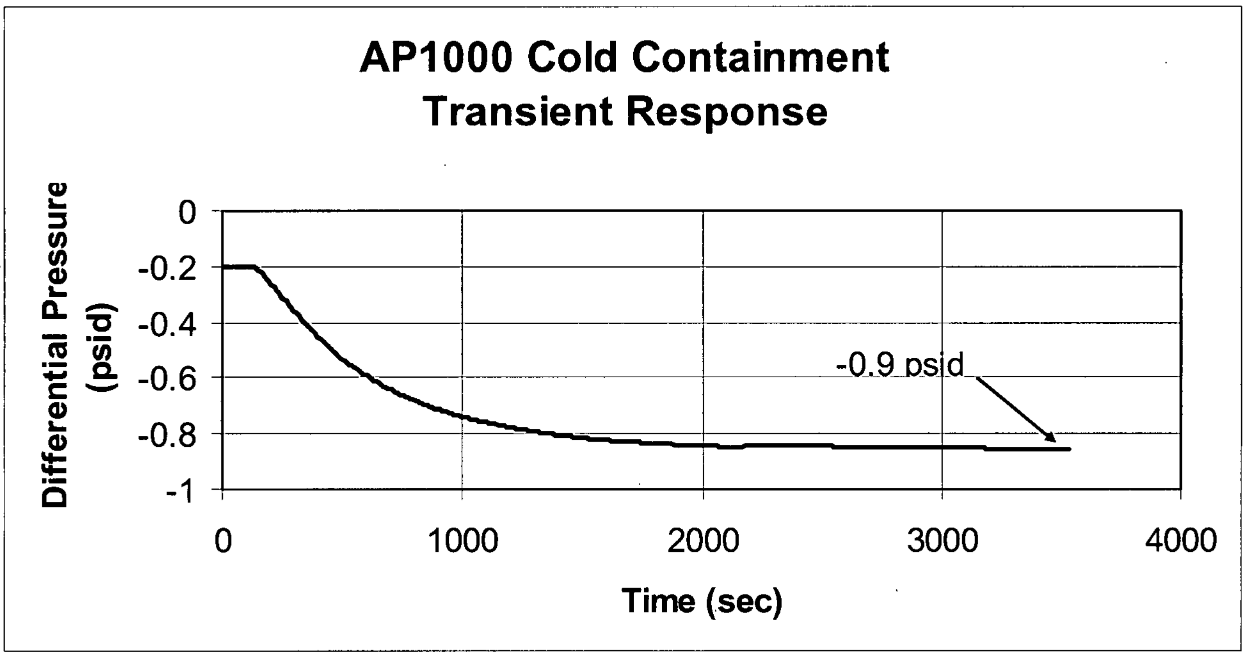
**Design Control Document (DCD) Revision:**

Revision 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. ~~Evaluations of these events show that an inadvertent actuation of active containment cooling 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 temperature reduction within the containment and an accompanying pressure reduction. Evaluations are performed to determine the maximum external pressure to which the containment may be subjected during a postulated actuation of active containment cooling.~~

~~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. With no active cooling in use the initial internal containment temperature is conservatively calculated to be 69°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.~~

~~Negative pressure is evaluated by assuming an inadvertent actuation of the active containment cooling. For AP1000, the passive containment cooling system provides heat removal from the containment shell to the environment via natural circulation air flow during normal operation. Since the passive containment cooling system water is relatively warm (minimum of 40°F) compared to the outside air temperature, actuation of this system results in a less limiting external pressure and shell temperature. Inadvertent actuation of the containment spray is not credible since the AP1000 containment spray requires significant local operator action to align the system. Inadvertent actuation of the containment fan coolers is the limiting event for external pressure at cold conditions.~~

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. ~~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 after the event the net external pressure~~

is approximately -0.9 psid, which is within the capability of the containment vessel. The pressure changes very slowly after the initial decrease, and there is sufficient time for operator action to prevent the containment pressure from dropping below the -0.9 psid 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 more realistic limiting case 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

# AP1000 TECHNICAL REPORT REVIEW

## Response to Request For Additional Information (RAI)

RAI Response Number: RAI-SRP-3.8.6-SEB1-01
Revision: 1

***Question:***

DCD Rev. 16, Section 3.8.6.1 has been revised to remove the COL information previously included in this section based on APP-GW-GLR-005 (Technical Report TR9) and the changes incorporated into the DCD. Provide the date at which the Westinghouse report APP-GW-GLR-005 will be revised to include the resolution of RAIs related to that report. If no revision is planned, so state.

**Request Revision 1**

To determine the adequacy of changes made to DCD Section 3.8.6.1 regarding COL information items related to TR-09 – Containment requires resolution of all TR-09 RAIs

**Westinghouse Response:**

Revision 2 of APP-GW-GLR-005 (Technical Report TR9) was transmitted 4/13/09 via letter DCP/NRC2423, "AP1000 COL Standard Technical Report Submittal of APP-GW-GLR-005, Revision 2 (TR-09)". This revision includes all changes proposed in the RAI responses.

**Response Revision 1**

The remaining unresolved issues on the review of the containment design and analysis are related to containment external pressure with extreme cold conditions. These issues are addressed in RAI-6.2.1.1-SPCV-07 Revision 1 and RAI-TR09-008 Revision 3.

The response to RAI-6.2.1.1-SPCV-07 Revision 1 explains that the information in Subsection 6.2.1.1.4 on external pressure is intended to be used to develop parameters for structural external pressure analysis and is not intended to be used for containment performance evaluations. This response revised the Design Control Document to remove most of the information in Subsection 6.2.1.1 on external pressure analysis.

RAI-TR09-008 Revision 3 contains changes to Subsection 3.8.2 to provide information on the external pressure analyses to replace information removed from Subsection 6.2.1.1. The service metal temperature in Subsection 3.8.2.6 is corrected. Conforming changes to Note 3 to Table 3.8.2-1 and Technical Specification Bases for B 3.6.4 are also provided.

Upon acceptance of the resolution outlined in RAI-6.2.1.1-SPCV-07 Revision 1 and RAI-TR09-008 Revision 3 the issues in the TR-09 RAIs will be considered resolved.

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

None

**PRA Revision:**

None

**Technical Report (TR) Revision:**

None

# AP1000 TECHNICAL REPORT REVIEW

## Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR09-008
Revision: 3

***Question:***
In TR-9, starting on p. 4, Westinghouse presents a justification for reducing the design external pressure from 2.9 psid to 0.9 psid, and states that "the extreme conservatism in the above analyses was reduced and an estimate of the external pressure was provided in the response to DSER Open Item 3.8.2.1-1." The staff reviewed the AP1000 SER and could not establish that this reduction has been specifically reviewed and accepted by the staff. The staff also reviewed AP1000 DCD, Rev. 15, and found that the design external pressure is specified to be 2.9 psid on page 3.8-1. Since there is no evidence that the reduction in design external pressure has been reviewed and accepted by the appropriate staff reviewers, and a determination of acceptability cannot be made by staff structural reviewers, Westinghouse must use the design external pressure of record (i.e., 2.9 psid) in demonstrating the adequacy of the containment penetration designs. Therefore, the staff requests the applicant to

- Demonstrate the design adequacy of the containment penetrations for a design external pressure of 2.9 psid.
- Confirm the design adequacy of the steel containment vessel (other than penetrations) for a design external pressure of 2.9 psid.

**Revision 2**

According to Westinghouse, the "inadvertent actuation of the containment coolers" event controls both the minimum service temperature and the external pressure loading for the steel containment shell. The Containment Performance reviewers must evaluate the hypothetical scenario, and either agree or disagree with Westinghouse's predicted minimum containment shell temperature, and the predicted external pressure loading. The structures and materials reviewers cannot resolve their technical issues until the "inadvertent actuation of the containment coolers" event is resolved. Refer to RAI-SRP 6.2.1.1-SPCV-07. A teleconference took place between W and staff reviewers responsible for structures, materials, and containment performance, in order to clarify for W what the issues are, related to each review area. W has an action to address these issues.

**Revision 3**

Resolution of RAI-TR09-008 is tied to the resolution of RAI-SRP6.2.1.1-SPCV-07. Explain inconsistencies in DCD Section 3.8.2.6, Table 3.8.3-1, and Tech Spec Bases B 3.6.4.

**Westinghouse Response:**

For consistency with Figure 6.2.1.1-11, the words 'at one hour' were deleted from the text in section 6.2.1.1.4 of the DCD, Revision 16. This change and all other DCD changes shown below were incorporated in Revision 5 of APP-GW-GLR-134 (Technical Report 134).

The description of the external pressure analysis in DCD subsection 6.2.1.1.4 will be revised as shown below. This analysis concludes that the limiting case containment pressure transient is an inadvertent actuation of active containment cooling during extreme cold ambient conditions.

The limiting external pressure and associated thermal transient is considered conservatively as a normal event and is evaluated against ASME Service Level A criteria. It is also conservatively evaluated in combination with the safe shutdown earthquake occurring at the time of minimum pressure against ASME Service Level D criteria.

The external pressure analysis in DCD subsection 6.2.1.1.4 would permit a reduction in the design external pressure for the containment vessel from 2.9 psid to 0.9 psid. Westinghouse does not intend to change the design of the containment vessel and will retain the 2.9 psid as the design external pressure which is evaluated against ASME design conditions. Westinghouse will also retain the specification requiring evaluation of the combination of the 2.9 psid design external pressure and the safe shutdown earthquake.

The containment vessel, including the penetrations, is designed for a design external pressure of 2.9 psid. The design external pressure is the second "design" case in DCD Table 3.8.2-1 and also shown as "Des2" in Table 2-4 of this report. The design external pressure plus SSE is considered in the first Service Level D case in DCD Table 3.8.2-1 and also shown as "D1" in Table 2-4 of this report. The lower external pressure of 0.9 psid is only used as part of the "inadvertent actuation of active containment cooling during extreme cold ambient conditions" event (cases A1 and D2 in Table 2-4).

**Response Revision 3**

To determine parameters and loading conditions for the structural evaluation of the containment pressure vessel shell for external pressure loading conditions, postulated accident scenarios are evaluated. These scenarios typically postulated a rapid temperature reduction in the containment atmosphere. These postulated accidents were defined in DCD Subsection 6.2.1.1. DCD Section 6.2 considers containment performance requirements and analyses. The placement of information about the external pressure transients in Subsection 6.2.1.1 has caused confusion in the review of Section 6.2. The resolution of RAI-SRP6.2.1.1-SPCV-07 is dependent on the removal of information on the external pressure analyses from Section 6.2.

Information on the external pressure analyses is added to DCD Subsection 3.8.2, as shown below, to replace information removed from Subsection 6.2.1.1. The service metal temperature in Subsection 3.8.2.6 is corrected. Conforming changes to Note 3 to Table 3.8.2-1 and Technical Specification Bases for B 3.6.4 are also shown below.

No additional changes to TR09 (APP-GW-GLR-005) are included in Revision 3 of this response

## Design Control Document (DCD) Revision:

Add the following to subsection 3.8.2.4.1.1

Negative pressure is evaluated by assuming an inadvertent actuation of the active containment cooling. For AP1000, the passive containment cooling system provides heat removal from the containment shell to the environment via natural circulation air flow during normal operation. Since the passive containment cooling system water is relatively warm (minimum of 40°F) compared to the outside air temperature, actuation of this system results in a less limiting external pressure and shell temperature. The net external pressure for this event is approximately -0.9 psid. Inadvertent actuation of the containment fan coolers is the limiting event for external pressure at cold conditions. Inadvertent actuation of the containment spray is not credible since the AP1000 containment spray requires significant local operator action to align the system.

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. This value is bounding and is based on a nonmechanistic condition.

These external pressure conditions are included in the loading combinations in Table 3.8.2-1

Revise the first paragraph of Subsection 3.8.2.6 as follows:

Materials for the containment vessel, including the equipment hatches, personnel locks, penetrations, attachments, and appurtenances meet the requirements of NE-2000 of the ASME Code. The basic containment material is SA738, Grade B, plate. The procurement specification for the SA738, grade B, plate includes supplemental requirements S1, Vacuum Treatment and S20, Maximum Carbon Equivalent for Weldability. This material has been selected to satisfy the lowest service metal temperature requirement of ~~-15~~ -18.5°F. This temperature is established by analysis for the portion of the vessel exposed to the environment when the minimum ambient air temperature is -40°F. Impact test requirements are as specified in NE-2000.

Revise Note 3 to Table 3.8.2-1 as follows:

3. Reduced pressure of 0.9 psid at one hour in event of inadvertent actuation of the containment fan coolers ~~loss of all ac transient~~ in cold weather.

The following revisions to Subsection 6.2.1.1.4 were provided in Revision 2 of this response. Please see the response to RAI-SRP6.2.1.1-SPCV-07 Revision 1 for more recent revisions to this subsection.

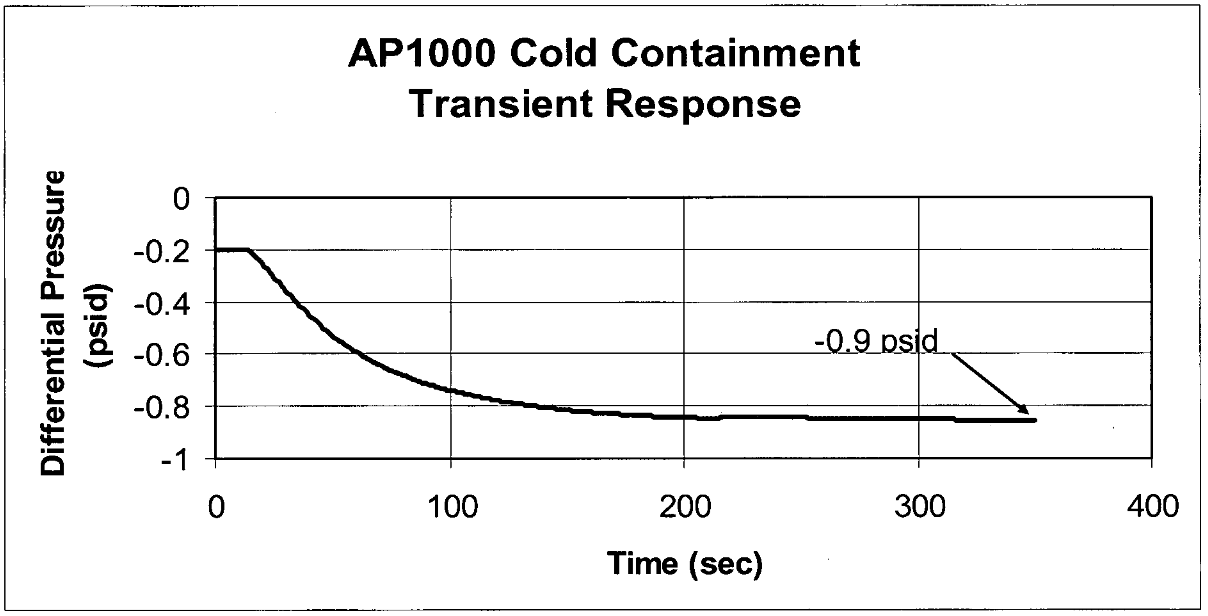
### 6.2.1.1.4 External Pressure Analysis

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 an inadvertent actuation of active containment cooling ~~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 maximum external pressure to which the containment may be subjected during a postulated actuation of the active containment cooling~~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. With no active cooling in use ~~T~~the initial internal containment temperature is conservatively calculated ~~assumed~~ to be 69~~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.

Negative pressure is evaluated by assuming an inadvertent actuation of the active containment cooling. For AP1000, the passive containment cooling system provides heat removal from the containment shell to the environment via natural circulation air flow during normal operation. Since the passive containment cooling system water is relatively warm (minimum of 40°F) compared to the outside air temperature, actuation of this system results in a less limiting external pressure and shell temperature. Inadvertent actuation of the containment spray is not credible since the AP1000 containment spray requires significant local operator action to alig~~h~~n the system. Inadvertent actuation of the containment fan coolers is the limiting event for external pressure at cold conditions.

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 approximately -0.9 psid which is within the capability of the containment vessel. The pressure changes very slowly after the initial decrease and there 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 -0.9 psid 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.



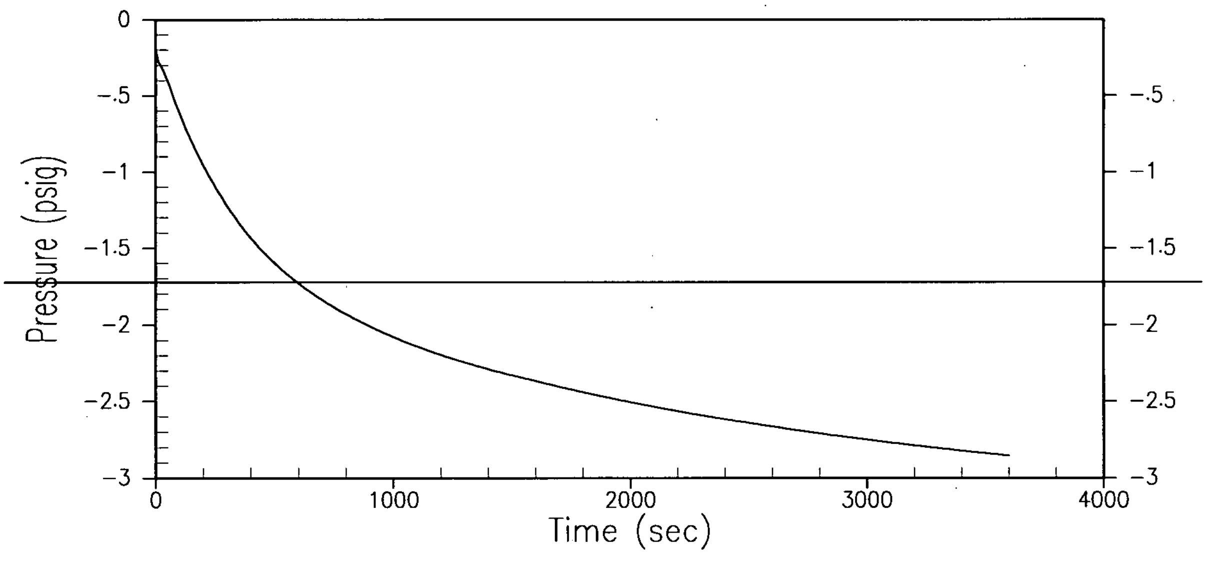




Figure 6.2.1.1-11 AP1000 External Pressure Analysis Containment Pressure vs. Time

The following revision is included as part of the Revision 3 response

Revise the third paragraph of APPLICABLE SAFETY ANALYSES in the Technical Specification Bases for B 3.6.4 Containment Pressure as follows:

> The containment was also designed for an external pressure load equivalent to 2.9 psig. The limiting negative pressure transient is ~~a loss of all AC power sources coincident with extreme cold weather conditions which cool the external surface of the containment vessel~~ based on a nonmechanistic step change in containment atmosphere at 120 degrees F, with 100% relative humidity, to the minimum operating temperature of 50 degrees F. The initial pressure condition used in this analysis was -0.2 psig. This resulted in a minimum pressure inside containment, as illustrated in Reference 1, which is less than the design load. Other external pressure load events evaluated include:
>
> Failed fan cooler control
>
> Malfunction of containment purge system

**PRA Revision:**
None

**Technical Report (TR) Revision:**

The technical report revisions shown below were included in Revision 2 of the response. Revision 3 of the response does not include additional technical report revisions.

Revise section 2.4 as shown below.

**2.4.1 External pressure and thermal loads**

Design conditions for the containment vessel are specified as:

- Design Pressure — 59 PSIG at design temperature of 280°F
- External Pressure — 2.9 PSIG at design temperature of 70°F

Both the maximum external pressure and the temperature conditions are affected by the ambient temperature. Combinations of normal temperature and external pressure are evaluated as service conditions as follows:

Service Level A

- Dead load, uniform temperature of 70F, design external pressure of 2.9 psid
- Dead load, cold weather temperature distribution one hour after inadvertent actuation of active containment cooling, reduced pressure of 0.9 psid one hour after inadvertent actuation of active containment cooling in cold weather. This conservatively includes the low probability inadvertent actuation of active containment cooling in cold weather event as a normal operating condition.

Service Level D

- Dead load, uniform temperature of 70F, SSE, design external pressure of 2.9 psid
- Dead load, cold weather temperature distribution one hour after inadvertent actuation of active containment cooling, SSE, reduced pressure of 0.9 psid one hour after inadvertent actuation of active containment cooling in cold weather

Two temperature conditions are considered corresponding to plant operation during cold weather with the outside air temperature at the minimum value of -40F and during hot weather with the outside air temperature at 115F. The cold weather operation results in a significant temperature differential in the vicinity of the horizontal stiffener at elevation 131' 9". The vessel above the stiffener is exposed to the outside air in the upper annulus. This cold weather condition is assumed concurrent with the pressure reduction resulting from inadvertent actuation of active containment cooling and is conservatively assumed as a normal operating condition. It is evaluated during normal operation as a Service level A event. It is also evaluated under Service level D in combination with the Safe Shutdown Earthquake.

~~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~~ The ~~design~~ external pressure of 0~~2~~.9 psid is based on conservative analyses as described in DCD subsection 6.2.1.1.4 (see Section 5.2 of this Technical Report). ~~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 into the containment during the transient. 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.~~

~~The extreme conservatism in the above analyses was reduced and an estimate of the external pressure was provided in the response to DSER Open Item 3.8.2.1-1.~~

~~With the postulated low outside temperatures, it is physically very unlikely, if not impossible (due to air cooling on the surface of the containment vessel) that the initial containment temperature will ever be 120 degrees F. A WGOTHIC calculation was performed to determine the containment pressure response with the containment initial temperature at as high a value as possible, and with the environment temperature as low as possible. An analysis was performed that determined that the highest containment atmosphere temperature that could occur would be 75F while the reactor is operating and the environment temperature is -40F.~~

~~To determine the reduced pressure, the following assumptions were made:~~

~~1.Initial containment conditions from steady state analysis; 75F, 100% relative humidity~~
~~2. Internal heat sinks inside containment are assumed to be 75F.~~
~~3Fan coolers remove operating reactor heat so that no net heat load to containment is assumed.~~
~~4. Environment temperature assumed to be -40F.~~
~~5. Heat transfer coefficients to heat sinks and containment shell are nominal.~~

~~Without an internal heat load, the containment atmosphere will cool and the pressure will decrease. The pressure falls from 14.5 psia to 13.6 psia (0.9 psid) at 3600 seconds after the heat input to the containment atmosphere is terminated. This is sufficient time for operator action to prevent further pressure reduction, as discussed in AP1000 DCD Section 6.2.1.1.4. Thus the design value of 2.9 psid external pressure is very conservative.~~

~~Note that the 0.9 psid considered in this second case is also conservative since it assumes no net heat load into the containment. Immediately after reactor trip the reactor coolant loop stays hot and heat loads to the containment remain close to those during normal operation. The fan coolers cannot operate with the assumption of loss of all AC; nor would they be expected to be providing cooling when the exterior temperatures are so low.~~

**Table 2-4 – Load Combinations for the Large Penetrations**

| Load | | | Design | | Level A Service Limit | | | Level C Service Limit | | Level D Service Limit | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Con | Test | Des1 | Des2 | A1 | A2 | A3 | C1 | C2 | D1 | D2 | D3 |
| D | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| $E_s$ | | | | | | | | 1.0 | | 1.0 | 1.0 | 1.0 |
| $P_t$ | | 1.0 | | | | | | | | | | |
| $T_t$ | | 1.0 | | | | | | | | | | |
| $P_o$ | | | | | | | | | 1.0 | | | |
| $P_i$ | | | 1.0 | | | 1.0 | | 1.0 | | | | 1.0 |
| $P_e$ (2.9psid) | | | | 1.0 | | | 1.0 | | | 1.0 | | |
| $P_e$ (0.9psid) | | | | | 1.0 | | | | | | 1.0 | |
| $T_o$ | | | | (4) | (5) | | (4) | | (4) | (4) | (5) | |
| $T_a$ | | | 1.0 | | | 1.0 | | 1.0 | | | | 1.0 |

**Notes:**
1. Service limit levels are per ASME-NE.
2. Where any load reduces the effects of other loads, that load is to be taken as zero, unless it can be demonstrated that the load is always present or occurs simultaneously with the other loads.
3. Reduced pressure of 0.9 psid at one hour in inadvertent actuation of active containment cooling ~~loss of all AC~~ transient in cold weather.
4. Temperature of vessel is 70F.
5. Temperature distribution for inadvertent actuation of active containment cooling~~loss of all AC~~ in cold weather.

Revise section 5.1 as shown below.

*5.1 DCD Changes from Rev 15 to Rev 16*

The DCD changes from Rev 15 to Rev 16 were shown in Rev 0 and Rev 1 of this report. DCD Rev 16 has been issued so these changes have been deleted from this section of the Technical Report.

Revise section 5.2 as shown below.

*5.2 DCD Changes to Rev 16*

The following revisions are to DCD Rev 16.

Revise classification in Table 3.2-3 as shown below from MC to Class 2 for penetrations where the process pipe penetrates directly the containment vessel without the use of a flued head (see typical detail on lower half of Figure 3.8.2-4, sheet 4 of 6). In this case the sleeve is a boundary of the process fluid and is required by the ASME Code to be Class 2.

Revise sheets 2, 3, 4 and 6 of Figure 3.8.2-4 as shown on the following pages to reflect detail design of the penetration reinforcement.

Add text and figure showing changes to subsection 6.2.1.1.4, “External Pressure Analysis” as shown in the DCD Revisions in this RAI response (pages 2 and 3 in this RAI response).