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Your ref: Docket No. 52-006
Our ref: DCP/NRC1661

December 23, 2003

SUBJECT: Transmittal of Revised Responses to AP1000 DSER Open Items

This letter transmits Westinghouse revised responses to Open Items in the AP1000 Design Safety Evaluation Report (DSER). A list of the revised DSER Open Item responses transmitted with this letter is Attachment 1. The non-proprietary responses are transmitted as Attachment 2.

Please contact me at 412-374-4728 if you have any questions concerning this submittal.

Very truly yours,

R. P. Vijuk, Manager
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/Attachments

1. List of the AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses transmitted with letter DCP/NRC1661
2. Non-Proprietary AP1000 Design Certification Review, Draft Safety Evaluation Report Open Item Responses dated December 23, 2003

D063

December 23, 2003

Attachment 1

List of

Non-Proprietary Responses

Table 1 "List of Westinghouse's Responses to DSER Open Items Transmitted in DCP/NRC1661"	
Reactor Systems Audit – Action Item 5 15.2.7-1 Item 7, Revision 2	

DCP/NRC1661
Docket No. 52-006

December 23, 2003

Attachment 2

AP1000 Design Certification Review
Draft Safety Evaluation Report Open Item Non-Proprietary Responses

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: **Reactor Systems Audit – Action Item 5**

Original RAI Number(s): none

Summary of Issue: PHRH HX ITAAC

During an audit of Westinghouse 11/18-20/03, the NRC questioned whether ITAAC 2.2-4, Item 8.b, PRHR Acceptance Criteria was comprehensive. Following this audit Westinghouse revised this ITAAC (revision 8 of the DCD) to add a second heat transfer test condition and the HX elevation.

In the NRC / Westinghouse meeting on 12/17/03, the NRC indicated that, "The Westinghouse proposed PRHR acceptance criteria with two HX transfer rates and the HX elevation in ITAAC, Revision 8, is acceptable. However, Westinghouse should ensure that the numerical values of heat transfer rates in the acceptance criteria bound the calculated PRHR HX heat transfer rates in the safety analyses."

Westinghouse Response:

Attached are the revisions that were made to the DCD and ITAAC in revision 8 of the DCD to incorporate a second PRHR HX ITAAC test condition and to add an inspection of the HX elevation. These additions provide confidence that the installed PRHR HX performance will be consistent with that used in the AP1000 safety analysis.

The ITAAC acceptance criteria for the PRHR HX heat transfer were calculated in a manner consistent with the safety analysis, using maximum line resistances, maximum number of tubes plugged and the ITAAC test conditions for the RCS HL and IRWST temperatures. The main difference between the ITAAC conditions and those in the DCD safety analysis is a lower IRWST temperature. The IRWST temperature was selected based on the conditions expected during ITAAC testing.

Design Control Document (DCD) Changes:

ITAAC Change to Table 2.2.3-4:

Table 2.2.3-4 (cont.)
Inspections, Tests, Analyses, and Acceptance Criteria

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
8.b) The PXS provides core decay heat removal during design basis events.	A heat removal performance test and analysis of the PRHR HX will be performed to determine the heat transfer from the HX. For the test, the reactor coolant hot leg temperature will be initially at ≥ 540°F with the reactor coolant pumps stopped. The IRWST water level for the test will be above the top of the HX. The IRWST water temperature is not specified for the test. The test will continue until the hot leg temperature decreases below 420°F.	A report exists and concludes that the PRHR HX heat transfer rate with the design basis number of PRHR HX tubes plugged is: ≥ 1.78 x 10^8 Btu/hr with 520°F HL Temp and 80°F IRWST temperatures. ≥ 1.11 x 10^8 Btu/hr with 420°F HL Temp and 80°F IRWST temperatures.
	Inspection of the elevation of the PRHR HX will be conducted.	The elevation of the centerline of the HX's upper channel head is greater than the HL centerline by at least 26.3 ft

Associated change to DCD, Table 14.3-2:

Table 14.3-2 (Sheet 7 of 17)

DESIGN BASIS ACCIDENT ANALYSIS

Reference		Design Feature	Value
Table	6. 3-4	The passive core cooling system has two pH adjustment baskets each with a minimum required volume (ft^3).	280
Section	14. 2. 9. 1. 3 f	The passive residual heat removal heat exchanger minimum natural circulation heat transfer rate (Btu/hr)	
		- With 520°F hot leg and 80°F IRWST	≥ 1.78 E+08
		- With 420°F hot leg and 80°F IRWST	≥ 1.11 E+08
Section	6.3.6.1.3	The centerline of the HX's upper channel head is located above the HL centerline (ft)	≥26.3
Figure	6. 3.-1	The CMT level sensors (PXS-11A/B/C/D, -12A/B/C/D, -13A/B/C/D, and -14A/B/C/D) upper level tap centerlines are located below the centerline of the upper level tap connection to the CMTs(in).	1" ± 1"

Associated change to DCD section 6.3.6.1.3:

6.3.6.1.3 Preoperational Inspections

Preoperational inspections are performed to verify that important elevations associated with the passive core cooling system components are consistent with the accident analyses presented in Chapter 15. The following elevations are verified:

- The bottom inside surface of each core makeup tank is at least 7.5 feet above the direct vessel injection nozzle centerline.
- The bottom inside surface of the in-containment refueling water storage tank is at least 3.4 feet above the direct vessel injection nozzle centerline.
- The centerline of the upper passive residual heat removal heat exchanger channel head is at least 26.3 feet above the hot leg centerline.
- The pH baskets are located below plant elevation 107 feet, 2 inches.

Inspections of the passive core cooling system tanks and pH adjustment baskets are conducted to verify that the actual tank volumes are greater than or equal to volume assumed in the Chapter 15 accident analyses. Inspections to determine dimensions of the core makeup tanks, accumulators, in-containment refueling water storage tank, and pH adjustment baskets are conducted, and calculations are performed to verify that actual volume is not less than the corresponding minimum required volume listed in Table 6.3-2.

Associated change to DCD section 14.2.9.1.3 f:

f) The heat transfer capability of the passive residual heat removal heat exchanger is verified by measuring natural circulation flow rate and the heat exchanger inlet and outlet temperatures while the reactor coolant system is cooled to ≤ 420°F. This testing is performed during hot functional testing with the reactor coolant system initial temperature ≥ 540°F and the reactor coolant pumps not running. The acceptance criteria for the PRHR HX heat transfer under natural circulation conditions are that the heat transfer rate is ≥ 1.78 E+08 Btu/hr based on a 520°F hot leg temperature and ≥ 1.11 E+08 Btu/hr based on 420°F hot leg temperature with 80°F IRWST temperature and the design number of tubes plugged. These plant conditions are selected to be close to the expected test conditions and are different than those listed in DCD Table 6.3-4. The PRHR HX heat transfer rate has been adjusted to account for these different conditions. The heat transfer rate measured in the test should be adjusted to account for differences in the hot leg and IRWST temperatures and number of tubes plugged.

PRA Revision:

None

AP1000 DESIGN CERTIFICATION REVIEW

Draft Safety Evaluation Report Open Item Response

DSER Open Item Number: 15.2.7-1 Item 7 Revision 2

Original RAI Number(s): None

Summary of Issue:

The revised DCD Section 15.6.5.4C (DSER OI 15.2.7-1P Page 14) states that the LTC phase analysis uses the NOTRUMP DEDVI case at 25 psia containment pressure reported in Section 15.6.5.4B as initial conditions, and the WGOTHIC analysis of this event as boundary conditions.

Please describe the model used to develop the containment backpressure and demonstrate that it represents a bounding and conservative estimate of containment pressure following a small break LOCA. Discuss any differences that may exist between this model and that used in the large break LOCA analyses. Please discuss how water spillage from a broken DVI line is mixed with the containment atmosphere and justify that the treatment is consistent with the Westinghouse ECCS evaluation model. Discuss the conservative treatment of non-safety related containment sprays and containment coolers in reducing containment pressure. Please also clarify if the 25 psia initial condition is consistent with the WGOTHIC analysis of the containment pressure as a function of time.

Westinghouse Response (Revision 2):

As a result of the assessment of the Westinghouse AP1000 small-break WGOTHIC containment model by the NRC Containment and Accident Dose Assessment Section (Ref: "An Assessment of the Westinghouse AP1000 Small-Break LOCA WGOTHIC Containment Model for Minimum Containment Pressure and Lon-Term Cooling," USNRC, November 2003), Revision 2 of this response has been prepared. Attachment A summarizes the NRC assessment and provides the Westinghouse response.

Original and Revision 1 Response:

For AP600 and AP1000, two different WGOTHIC models were used to determine the containment backpressure that would exist following a LOCA event. Assumptions were used in these models to conservatively underpredict the pressure. These two models are discussed below.

Large Break LOCA Model for PCT Calculation

For this case, a simplified WGOTHIC model of the containment was developed to determine the containment pressure response during the blowdown portion of a double-ended cold leg break. This model consists of a single control volume that represents the containment, all the heat sinks inside containment, and a simplified thermal conductor representing the containment shell that is connected from the containment control volume to a control volume that represents the environment. The boundary conditions for this model are specified in Reference 1. The outside temperature of the shell is held at a constant temperature of 0F. The heat transfer coefficient inside containment consists of the Tagami correlation for the blowdown portion of the transient (first 29 seconds), and the Uchida condensation correlation for the time following blowdown. These heat transfer coefficients are applied on all the internal heat sinks as well as the inside of the containment shell. As specified in Reference 1, the Tagami correlation is multiplied by a factor of four, and the Uchida correlation is multiplied by a factor of 1.2.

Small Break LOCA Model to Determine Containment Backpressure

A second WGOTHIC model was used to determine the AP600 and AP1000 containment backpressure after a small break LOCA event. These results were used as the boundary conditions for small break LOCA NOTRUMP analyses and WCOBRA/TRAC long term cooling analyses. The model is the same as the evaluation model used to determine the peak containment pressure for the DCD with assumptions changed to minimize the pressure response. For AP600, this model was used to support the long term cooling analysis, but was not used for the small break LOCA backpressure. For AP1000, this model was used to support the long term cooling analysis as well as the double-ended DVI (DEDVI) break analysis.

This model is described in Reference 2 which was submitted to the NRC and reviewed as part of AP600 Design Certification. As specified in Reference 2, the following changes to the DCD WGOTHIC model were made for this analysis:

1. The DCD model is biased to maximize containment pressure. These assumptions were changed for the backpressure analysis to minimize containment pressure.

   - Heat transfer coefficient multipliers which are set to values less than unity for the peak pressure analysis are set to unity for the backpressure analysis
   - Heat sinks that are conservatively neglected for the peak pressure analysis are included for the backpressure analysis
   - Initial conditions inside containment that are biased to the highest operating pressure and temperature are set to the lowest operating pressure and temperature. Relative humidity is set to 100% to minimize the initial air inventory inside containment. Environmental boundary conditions are biased to maximize heat transfer from the passive containment cooling system and minimize the containment pressure.
   - The containment vent system is assumed to be open at the start of the event and closes on an SI signal. This allows an initial decrease in the air inventory which results in a lower containment pressure

2. Mass and energy release rates that are specific for the double-ended DVI break are included in the WGOTHIC model.

   - Water spilling from the broken DVI is assumed to enter the PXS compartment containing the break. This water does not interact with the containment atmosphere as it falls from the break.

Non-safety systems such as containment fan coolers and containment sprays are not considered for this analysis. The containment spray system is only used in the event of severe accidents. Its use requires the operator to align the pumps and water sources for operation (requires an operator to open manual valves out in the plant). The chilled water supply to the fan coolers is automatically isolated following an SI signal. The system can be restarted by the operator to assist in long-term recovery following a LOCA, and it is not considered in this shorter-term analysis.

Two sensitivity studies were done to determine the effect of these assumptions.

Cold Water Spill Sensitivity

The DEDVI break consists of two break flow paths; one from the vessel side, and one from the loop side. The vessel side break is a typical high-temperature, high-pressure two-phase blowdown. This two-phase flow is assumed to form droplets that are dispersed into the atmosphere of the break compartment. The recommended drop size is 100 microns. The loop side break flow consists of low-temperature (~80F), high-pressure single phase water. Normally, this water is spilled to the floor of the compartment and is not assumed to interact with the vapor-space region of the compartment. For this sensitivity study, the loop side break flow is assumed to be dispersed into the atmosphere of the break compartment.

Figure 1 shows the containment pressure response for the two cases. By allowing the cold water to interact with the steam and two-phase mixture in the compartment vapor space, the overall pressure is reduced by approximately 2 psi. The pressure remains above 25 psia between the time that the ADS4 flow becomes non-critical and the time of IRWST injection. The interaction between the steam and the water droplets in the compartment causes steam to condense resulting in less steam to pressurize the containment. In addition, the water droplets are heated so that the water accumulating on the compartment floor is saturated.

Heat Transfer Coefficient Sensitivity

The Tagami correlation is not considered appropriate for use in small break LOCA analysis. This correlation was developed to account for significant forced convection heat transfer that takes place during the blowdown period of a large break LOCA. This time period is about 30 seconds. For the DEDVI, the "blowdown" period extends to about 500 seconds during which an equivalent amount of energy is released from the RCS to the containment atmosphere as occurs for the large break LOCA. Since the forced convection in containment depends on a characteristic velocity, the velocities inside containment during the blowdown period can be compared for the two events by comparing the blowdown time. Thus, it is likely that the velocities would be at least a factor of ten lower for the DEDVI than for the DECL during the blowdown, and since the forced convection heat transfer coefficient is roughly proportional to the velocity, use of Tagami during a small break LOCA blowdown would significantly overpredicit the forced convection heat transfer. The Uchida correlation is recommended for these analyses.

As a sensitivity, the multiplier on the Uchida correlation was increased to 4.0 during the blowdown period (<500 seconds). Figure 2 shows the containment pressure response with and without this multiplier assuming mixing of the cold water spill as described above. These results show little sensitivity to the increased heat transfer coefficient.

The results of these sensitivity studies show that the containment backpressure boundary condition of 25 psia is valid for use in the DEDVI small break LOCA analysis.

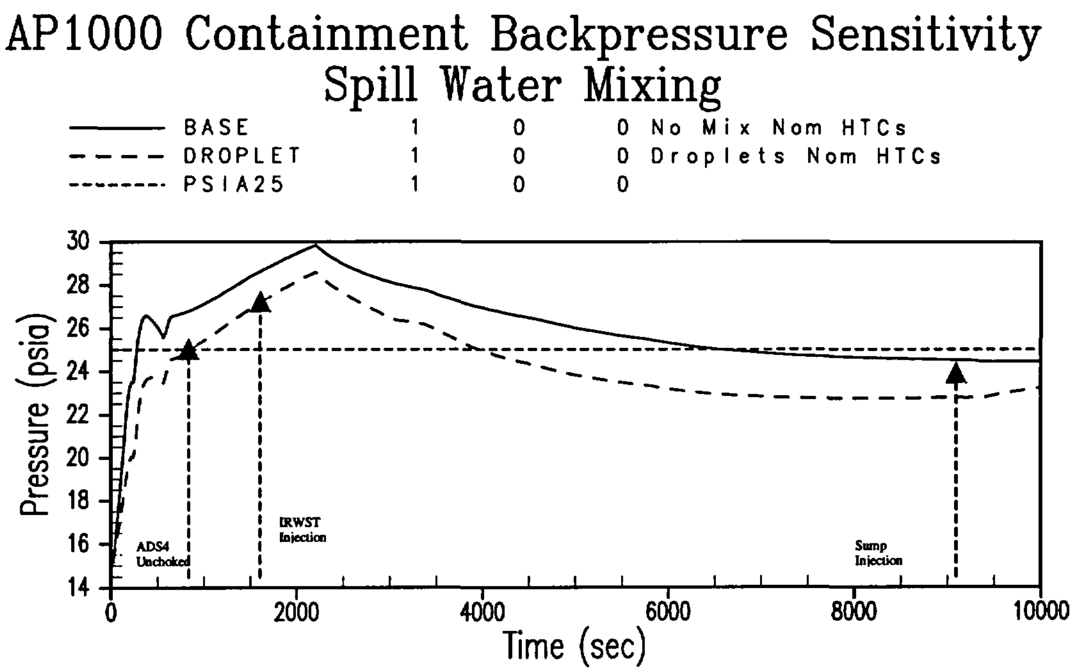

Figure 1: Cold Water Droplet Size Sensitivity

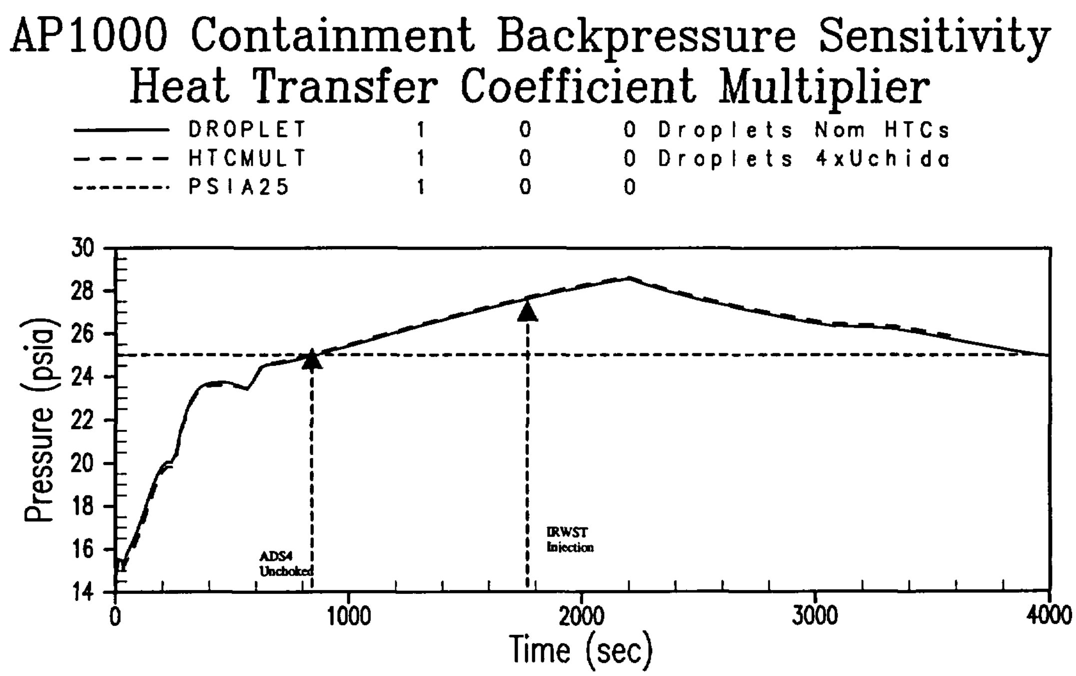

Figure 2: Heat Transfer Multiplier Sensitivity

References

1. WCAP-14171, Rev 2, WCOBRA/TRAC Applicability to AP600 Large Break LOCA March 1998.

2. WCAP-14601, Rev 2, AP600 Accident Analysis Evaluation Models, May 1998.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

Attachment A

Summary of NRC Assesment

Bounding Containment Backpressure for AP1000 Long-Term Cooling

The NRC staff asked for a description of the model used to develop the containment backpressure for small-break LOCA and long-term cooling (DSER Open Item 15.2.7-1 Item 7 [Ref 1]). In addition, the staff asked for a discussion of the differences between this model and the model used for minimum pressure following a large-break LOCA. Specifically, the staff asked Westinghouse to discuss how cold water spilled from the broken DVI line interacts with the containment atmosphere, and to discuss the role of non-safety equipment such as fan coolers and containment sprays for these analyses.

The Westinghouse response to this open item is summarized as follows:

1. The WGOTHIC model for small-break LOCA backpressure and long-term cooling is consistent with the methodology in WCAP-14601, "AP600 Accident Analyses – Evaluation Models," Rev 2 (Ref 2).

2. The use of the Tagami correlation is not appropriate for small-break LOCA analyses.

3. Heat sinks that are removed for the peak pressure calculation are included in the small-break LOCA backpressure and long-term cooling calculation

4. Non-safety fan coolers and containment sprays require specific post-accident operator action and would not be available during the time frame prior to sump recirculation switchover.

5. The cold water spill was introduced to the containment atmosphere as a fine mist (100-micron drops) and the resulting containment pressure was reduced by approximately 2 psi.

The Westinghouse response to the Open Item was referred to the Containment and Accident Dose Assessment Section for further review. The NRC staff prepared an assessment of the AP1000 Small-Break LOCA WGOTHIC Containment Model for Minimum Containment Pressure and Long-Term Cooling (Ref. 3). The assessment concluded the following:

1. The AP1000 small-break LOCA and long-term cooling minimum containment pressure methodology is consistent with WCAP-14601, "AP600 Accident Analyses – Evaluation Models," (Ref. 4). Key assumptions for this analysis are summarized below:

    - the containment volume is 1.05 times the best estimate value

- the initial containment temperature is 120F
- the passive heat sink areas are 1.05 times the best estimate values
- the PCS water flow is set to the maximum value and water coverage is set to the maximum value
- no penalties are applied to the PCS heat and mass transfer correlations

2. The AP1000 small-break LOCA and long-term cooling minimum containment pressure methodology differs from the methodology used to determine the minimum pressure for large-break LOCA as described in the AP600 and AP1000 Tier 2 DCD Section 6.2.1.5 (Ref. 5). These differences are summarized below:

   - the containment volume is 1.1 times the reference value
   - the passive heat sink surface areas are 2.1 times their reference values
   - the material properties are biased high
   - the air annulus and containment shell temperatures are assumed to be held at a constant 0F
   - the containment purge is operated at time zero and closes 12 seconds after the pressure setpoint of 8 psig is reached
   - the initial containment pressure and temperature are set to their low values (14.7 psia, 90F) consistent with SRP 6.2.1.5
   - the containment relative humidity is set to 99%
   - the Tagami correlation with a multiplier of 4.0 is used for the blowdown

3. The staff concluded that use of the Tagami correlation was not justified for small-break LOCA. It was recommended that the Uchida correlation with a 1.2 multiplier be used.

4. It is the staff's recommendation that the WGOTHIC small-break LOCA and long-term cooling model be modified to include the most conservative assumptions from the WGOTHIC minimum pressure for large-break LOCA model. Specifically,

   a. The containment net volume should be increased by a factor of 1.1
   b. The containment shell and PCS heat structure area should be increased by a factor of 1.1
   c. The remaining head structure areas should be increased by a factor of 2.1 or a lower value if justified based on an accounting of expected structures in the final as-build plant.
   d. The Uchida correlation with a multiplier of 1.2 should be used for passive heat structures (non PCS structures throughout the accident.
   e. The PCS heat and mass transfer correlation multipliers should be appropriately biased to account for the uncertainty in the experimental data base, and forced convection should be included on the PCS inner surface
   f. Head transfer in dead-ended compartments below the operating deck should not be turned off at the end of blowdown.

g. The air-gap between the steel and the concrete should be reduced from the 20-mill thickness used in the maximum pressure calculation. A zero thickness air-gap would be conservative.
h. The material properties should be biased high for conservatism.
i. Heat transfer credit for the PCS should start earlier than is currently assumed for the maximum pressure calculation.
j. Westinghouse should maintain its treatment of ECCS spillage as implemented in 1979.
k. The containment purge system should be assumed to be operating and isolate on high pressure signal
l. The initial and boundary conditions for the PCS water and environment should be provided with their justification for staff review.

Westinghouse response:

The NRC recommendations listed above were incorporated into the WGOTHIC small-break LOCA and long-term cooling model, and the pressure response to a double-ended DVI break LOCA is shown in Figure A-1 as the NRC case. Also shown as the base case is the pressure using the assumptions from the approved methodology in Reference 2.

The following are Westinghouse comments regarding the recommendations of the staff assessment and discussion of the parameters used in the WGOTHIC analyses for Figure A-1:

a. The main parameters of the volume enclosed by the containment shell are established by an ITAAC that requires the dimension of the shell inside diameter and height above the operating deck. Major structures and components inside containment are also identified in ITAAC. Uncertainties associated with the volume of the structures and equipment inside containment will result in a small uncertainty in the net free volume. The base case uses a multiplier of 1.05 to conservatively account for this uncertainty. The NRC case uses a multiplier of 1.1.

b. The containment shell dimensions (shell inside diameter and height above the operating deck) are established by ITAAC. Also the water film on the external surface of the containment shell is assumed to distribute evenly around the entire circumference of the containment shell to maximize the effectiveness of the PCS heat transfer area. The base case uses a factor of 1.05 on PCS heat transfer area to conservatively account for any residual uncertainty in PCS heat transfer area. The NRC case uses a factor of 1.1 for this uncertainty.

c. The methodology for the WGOTHIC small-break LOCA and long-term cooling containment backpressure was approved for AP600 in Reference 2. The WGOTHIC model for minimum backpressure for large-break LOCA was completed before the passive heat sink information was finalized. Consequently, the passive heat sink area multiplier in the approved methodology, 1.05, was doubled to account for this uncertainty to 2.1. Since the results were within acceptable margins, there was no need to repeat the analysis as the design matured and the passive heat sinks were better defined. This large overconservatism was noted by the staff during review of AP600. The base case in Figure A-1 uses a 1.05 multiplier on heat sinks. The NRC case uses a 2.1 multiplier on heat sinks.

d. As was noted in Reference 3, the use of the Tagami correlation is not appropriate for small-break LOCA. For the base case analysis the Uchida correlation is used with a 1.2 multiplier during blowdown and 1.0 multiplier after blowdown. For the NRC case the Uchida correlation is used with a 1.2 multiplier throughout the accident simulation.

e. The base case uses multipliers of 1.0 on the PCS heat and mass transfer correlations. For the NRC case these multipliers were 1.19 and 1.37. Since WGOTHIC is being used in the lumped-parameter mode, the gas velocity is not known in the cells adjacent to the shell. Considering that velocities will be small for small-break LOCA events, forced convection is not modeled for either case.

f. For both cases heat transfer in the dead-ended compartments was not turned off at the end of blowdown as recommended.

g. The base case includes the air gap thickness. The air-gap thickness was eliminated for the NRC case.

h. The material properties for steel, concrete and air were set to nominal values in the base case. For the NRC case, the properties were biased to maximize heat absorption.

i. The PCS startup time was accounted for in the base case. The PCS was started at full flow at the start of the transient for the NRC case.

j. The base case treats ECCS spillage as liquid flowing to the containment sump without interaction with containment atmosphere. Consistent with the Revision 1 of this Open Item response, for the NRC case the ECCS spillage is treated as a mist with a droplet size of 100 microns to maximize the heat transfer with the containment atmosphere.

k. For both cases the containment purge system is assumed to open and isolates on a high containment pressure signal.

l. For both cases the initial temperature (120F) and the initial humidity (100%) inside containment are biased high to minimize the amount of non-condensable gas at the start of the transient. For both cases the initial temperature and PCS temperature outside containment are biased low (40F) to maximize heat removal from the containment shell.

The NOTRUMP small-break LOCA response, and the WCOBRA/TRAC long term cooling response will be re-analyzed using the NRC case for the AP1000 DEDVI break. The results will be submitted in another revision to this response.

References

1. DSER Open Item 15.2.7-1 Item 7 Revision 1
2. WCAP-14601, "AP600 Accident Analyses – Evaluation Models," Rev 2
3. Assessment of the AP1000 Small-Break LOCA WGOTHIC Containment Model for Minimum Containment Pressure and Long-Term Cooling, E. Throm, USNRC, December 2003.
4. WCAP-14601, "AP600 Accident Analyses – Evaluation Models"

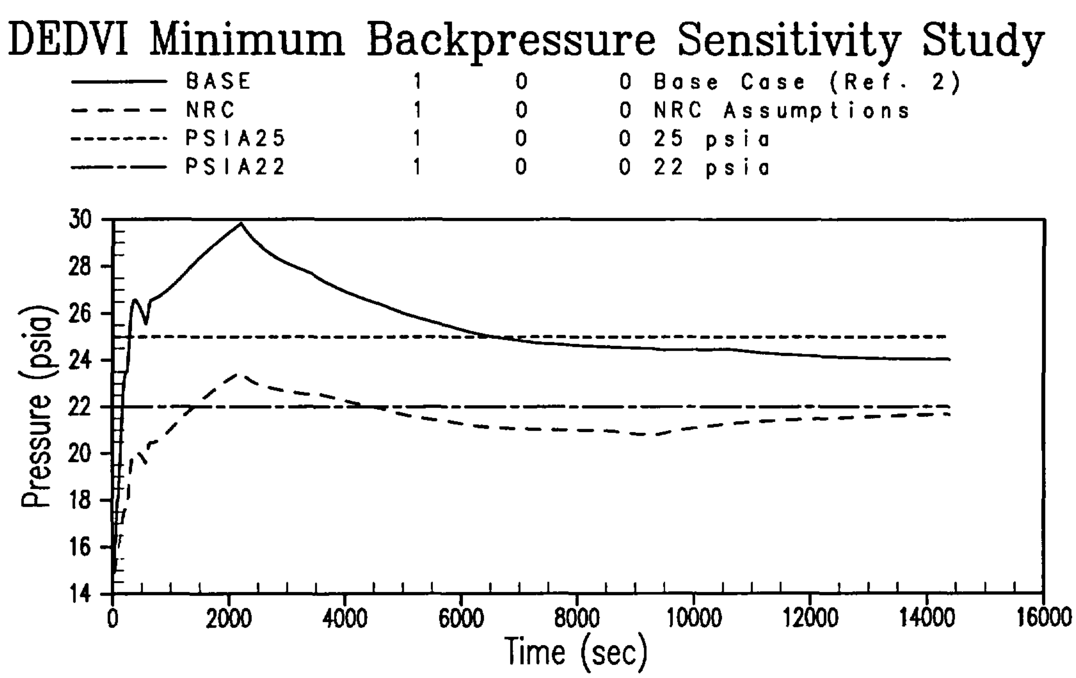

Figure A-1: AP1000 Containment Backpressure Sensitivity