Docket File

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 24, 1997

Mr. Nicholas J. Liparulo, Manager
Nuclear Safety and Regulatory Activities
Nuclear and Advanced Technology Division
Westinghouse Electric Corporation
P.O. Box 355
Pittsburgh, Pennsylvania 15230

SUBJECT: REQUESTS FOR ADDITIONAL INFORMATION (RAIs) ON WCAP-14845, "SCALING ANALYSIS FOR AP600 CONTAINMENT PRESSURE DURING DESIGN BASIS ACCIDENTS"

Dear Mr. Liparulo:

The Nuclear Regulatory Commission's (NRC) Containment Systems and Severe Accident Branch staff reviewed WCAP-14845, "Scaling Analysis for AP600 Containment Pressure During Design Basis Accidents" and determined that it needs additional information in order to complete its review of the Westinghouse AP600 passive containment cooling system and WGOTHIC computer code. Enclosure 1 is questions and concerns, identified as RAIs #480.967 to 480.1036. In addition to the RAIs, Enclosure 2 is apparent typographical errors and inconsistencies that have been identified for Westinghouse. This is the first of two requests on WCAP-14845, with additional RAIs to follow based on commitments from the April 18, 1997, meeting with Westinghouse on the scaling study. It is expected that WCAP-14845 will be updated to reflect the questions and comments enclosed in this letter.

The RAIs address both the Executive Summary and the body of the report. However, comments are not repeated for material that appears both in the body and in the summary. Therefore, any changes made to the body of the report in response to the comments and requests for additional information should be reflected in the Executive Summary.

You have requested that portions of the information submitted in the June 1992, application for design certification be exempt from mandatory public disclosure. While the staff has not completed its review of your request in accordance with the requirements of 10 CFR 2.790, that portion of the submitted information is being withheld from public disclosure pending the staff's final determination. The staff concludes that these questions and comments do not contain those portions of the information for which exemption is sought. However, the staff will withhold this letter from public disclosure for 30 calendar days from the date of this letter to allow Westinghouse the opportunity to verify the staff's conclusions. If, after that time, you do not request that all or portions of the information in the enclosures be withheld from public disclosure in accordance with 10 CFR 2.790, this letter will be placed in the NRC Public Document Room.

DF03

If you have any questions regarding this matter, you may contact me at (301) 415-8548.

Sincerely,

original signed by:

Diane T. Jackson, Project Manager
Standardization Project Directorate
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Docket No. 52-003

Enclosures: As Stated

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Docket No. 52-003
AP600

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Enclosure to be distributed to the following addressees after the result of the proprietary evaluation is received from Westinghouse:

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REQUESTS FOR ADDITIONAL INFORMATION

Scaling Analysis for AP600 Containment During Design Basis Accidents
WCAP-14845, February 1997

The comments below address both the Executive Summary and the body of the report. However, comments are not repeated for material that is in the body and in the summary. Therefore, any changes made to the body of the report in response to the comments and requests for additional information should be reflected in the Executive Summary.

480.967 (General) Many of the numbered equations, e.g. (1), contain multiple formulas and it is difficult to tell when one formula ends and another begins. Insert semicolons or some other separator so it is clear where the separation between formulas is intended.

480.968 (Page xv) Table E-1 has no π groups listed for Liquid Film Energy Transport, while Table 2-1 has two π groups listed. A second π group is missing in Table E-1 for Radiation Heat Transfer. Also, what is the basis for the 14 percent of condensation energy carried away by the film on the inside and 8 percent on the outside?

480.969 (Page xl) Two points in Table P-1 should be clarified. The need was apparently identified for a 1/8 scale test and also for testing to determine the effect of hydrogen on heat transfer. Was the need for the 1/8 scale test satisfied by the large scale test (LST)? If so, it would help to state this. Also, this is the only mention of hydrogen effects. It would help to state how this concern was addressed.

480.970 (Page xxiii) The differences between the results of the scaling model and the evaluation model will need to be explained in more detail than what is provided here.

480.971 (Page xxxiv) The wording in the first paragraph needs to be changed to have the same meaning as in the body of the report on Page 10-20. The transient π group $\pi_{e,t}$ clearly does not equal zero as stated here. (See wording in Section 10, Page 10-20.)

480.972 (Page xlii) The last paragraph in Element 2 refers to the distributed parameter WGOTHIC calculations. If these calculations are no longer a part of the submittal this reference should be deleted.

480.973 (Page xlii) Where are the sensitivity calculations referred to in Element 3 documented? Give a reference.

480.974 (Page 1-3) The third bullet makes reference to "LASL." Should this reference be to Sandia?

Enclosure

480.975 (Pages 2-2 and 2-3) The table given here is very useful in locating where each phenomena is addressed. However, some of the π groups could not be found in Section 8, where π groups are evaluated. These are: $\pi_{p,g,j}$, $\pi_{e,f,ff}$, $\pi_{e,c,j}$ and $\pi_{e,r,j}$. Also, listing "parameter" under π group does not give any information on where the phenomenon is addressed. It would help to show which π group the parameter is in.

480.976 (Page 2-3) No π group is listed for baffle conduction in Table 2-1. Why are $\pi_{e,q,bf}$ and $\pi_{e,q,bfx}$ listed in Table 8-4 not appropriate for addressing this phenomenon?

480.977 (Pages 3-1 and 3-2) Values given for the volumes and surface areas of steel and steel-jacketed heat sinks are different from those given in (Phenomena Identification and Ranking Table) PIRT (WCAP-14812) Table 3-1. Please explain.

480.978 (Page 3-3) Why is the third plateau in mass flow rate beyond 80,000 seconds not shown in Figure 3-1 as it is in PIRT (WCAP-14812) Figure 3-7? Is the correct flow rate beyond 80,000 seconds shown in the PIRT Figure?

480.979 (Page 3-10) Please explain the decrease in pool surface area which occurs between 2,500 and 5,000 seconds shown in Figure 3-8.

480.980 (Page 4-7, Section 4.3.2) What is the basis for the belief that the correlation for the air-steam diffusion coefficient produces values which are 10 percent high? Why is this acceptable?

480.981 (Page 6-1, Section 6) The wording of the last sentence in this section could be modified to better convey the thought. It appears that you have adopted and adhered to a sign convention and this assures that the direction of heat flow is unambiguous and determined by the sign of the solution.

480.982 (Page 6-7) The statement that u_{min} can be defined which corresponds to the system with the specific internal energies of water and air at the same temperature and pressure needs further explanation.

480.983 (Page 6-7) It would be helpful to the reader to state that Equation (56) in the form:

$$dm_{stm}/dt = m_{g,brk} - S\ m_{stm,j}$$

is used to obtain Equation (67).

480.984 (Page 6-9) In Equation (69), the work term has been left out of the final equation, although a π group for the term is included. When the equation is used in Chapter 9, as Equations (191) and (197), this same term is also missing. Please explain.

480.985 (Page 6-16) In Table 6-3, it would be helpful to add the time period for each phase to the headings.

480.986 (Page 6-18) According to the nomenclature section, ρ_a in Equation (84) is the containment ambient density. How is this number calculated from the reference values given in Table 6-3? What phase of the DECLG LOCA (double ended cold leg guillotine loss-of-coolant-accident) is used to get the values in Table 6-4? How is the value determined for LST?

480.987 (Page 6-18) The criterion for stable stratification, based on the volumetric Froude number, does not include the diameter of the large volume within which the jet is released. This means that the criterion applies equally to a volume whose diameter is only slightly larger than the jet diameter, d_o, and to an infinitely large diameter volume. There must be some assumption in Peterson's approach which limits the size of the applicable volume relative to the jet. Clearly, a jet located in an infinitely large volume does not affect the stratification of the entire volume. Please explain the limitations on the application of Peterson's approach as the volume size increases.

480.988 (Page 6-22) Fr_v at the stability limit presented in Table 6-4 is stated to be calculated using Equation (89),

$$Fr_v = (1 + d_o/(4 \sqrt{2}\ a\ H))^2$$

$$Fr_v = (1 + 11.1/(4 \sqrt{2}\ 0.05\ 109))^2$$

$$Fr_v = 1.85$$

which doesn't agree with the number in the table. Please explain.

480.989 (Page 7-7, Section 7.1.1) A formula for the shell conductance is given just before Equation (96) which includes the coating on both sides. Later, on the bottom of Page 7-11, a formula for the conductance is given without the coatings. Which formula was actually used?

480.990 (Page 7-13, Table 7-2) What is the reason for choosing the design pressure (60 psia) as "P" total for the long term phase? Would this not tend to overestimate the heat transfer to the heat sinks?

480.991 (Page 7-13, Table 7-3) Why does the table not include the long term phase? Why is the pool surface area different for the blowdown and refill phases even though the pool volume is the same? Why is the surface area during refill different in Tables 7-2 and 7-3? Figure 3-8 shows a pool surface area of 2,000 ft^2 compared to the 1,933 ft^2 shown in this table. Which is correct?

480.992 (Page 7-15) How was the film determined to be less than approximately 0.005 inches thick, as stated in the first paragraph. The arguments regarding the importance of the liquid film are based on this assumption. How would the assumption of a thicker film affect the calculated heat transfer through the shell?

480.993 (Page 7-16) How was the 165°F area-weighted average film temperature cited in the first paragraph calculated?

480.994 (Page 7-21, Section 7.5.5) In Section 3 (Page 3-1) and Section 4.7, steel heat sink thickness is given as 0.4 inches, while 0.5 inches is used here. Which is correct?

480.995 (Page 7-21, Section 7.5.5) Using 25 B/hr-ft-F for the conductivity of carbon steel and the average steel thickness of 0.5 inches, indicates that an h of 48 B/hr-ft^2-F was used to get a Biot number of 0.08. Apparently this is $h_{e,o}$. However, according to the values in Table 8-2, $p_{c,et}$ has an average value of about 0.4, indicating that $h_{e,o}$ is approximately 0.4 x 216.58 = 86.6 B/hr-ft^2-F. How was the value of 48 for $h_{e,o}$ determined?

480.996 (Page 7-21, Section 7.5.5) Please explain in greater detail how the solution of Equation (118), given by Equation (126), was determined. In particular, what value was used for the containment atmosphere temperature and how was T_{erf} determined or related to T_{hs}?

480.997 (Page 7-21, Section 7.5.6) It is stated that the containment boundary condition was modeled as a step function over each time phase. What constant value was used for each phase?

480.998 (Page 7-22, Section 7.5.6) Were integrations performed to obtain the time averaged value of h_c? Please explain which equation(s) were integrated or how the average values were determined. Since the peak containment gas temperature is used for T_∞, what is an estimate of the error in the overprediction of heat flux during the non-peak pressure phases? Where was Equation (128) used outside of containment? What temperature was used for T_∞ outside of containment?

480.999 (Page 7-22, Section 7.5.7) It is stated that the modeling of two structures in parallel and taking the larger of the two is conservative for the steel-jacketed heat structures. This neglects the thermal resistance of the gap between the steel and the concrete, a factor considered in present evaluation models. Provide an estimate of the effect of the gap on your thermal model for the steel-jacketed heat sinks.

480.1000 (Page 7-25) Is Equation (134) based on treating the shell as a lumped mass? Please define the term T_{shx} (not in the nomenclature). Is T_{shx} assumed to be equal to T_{sh}?

480.1001 (Page 7-25, last paragraph) What calculation of the "temperature of the evaporating film independently of the subcooled or dry regions" is referred to here? Please describe the calculation.

480.1002 (Page 7-25) Please explain the meaning of Equation (135). The numerator is the energy flow rate needed to heat the external film flow from T_{in} to $T_{xf,e}$. One would expect the denominator to be the heat flux from the interior containment gas volume needed to heat the film flow over the area A_{sc}. Based on the nomenclature section, the heat transfer coefficient $h_{xf,es}$ is between the subcooled shell interior and the external film, but the temperature difference is between the film and the subcooled shell external surface, with the sign indicating that the film is expected to be at a higher temperature than the subcooled shell exterior surface. Please explain or correct the equation.

480.1003 (Page 7-29, last paragraph of Section 7.6.3) The reader can not tell what the relative magnitudes of time constants are from the equations in (140). It would be helpful to give the values to support the argument. Also, is the external heat transfer from the shell, rather than to the shell?

480.1004 (Page 7-30, Section 7.6.5) Which equation from Wulff is used to get the 22-second penetration time? If this is your Equation (151), this should be noted. What is the difference between this 22-second penetration time and the 18.4 seconds on page 7-31?

480.1005 (Page 7-30, Section 7.6.5) Please explain how you apply the adiabatic boundary condition at the outer shell surface during blowdown when you are using the thermally thick structure model. The last sentence of the first paragraph of Section 7.6.5 implies that this is being done. If the thermally thick structure is used for the entire blowdown period, please provide an estimate of the non-conservatism introduced by this approximation.

480.1006 (Page 7-31) In Equation (152), it seems that (in Wulff's notation) g_1 and g_2 are taken as 1/2 when they should be 1/3.

480.1007 (Page 7-32, Section 7.6.5) Equation (153) is incorrect. The equation $d\bar{T}/dt = C_1 - C_2\bar{T}$ given in the line below Equation (153) is correct with C_1 and C_2 as defined in (155). $\bar{T}(t_0) = \bar{T}_0$ is an initial condition for this ordinary differential equation, not a boundary condition. Please correct.

480.1008 (Page 7-33, second paragraph) The wetted area below the second weir is given as 44662 ft^2. Actually, this is the total area below the second weir (52662 - 8000 = 44662). The 90 percent wetted area fraction has not been applied below the second weir. The maximum wetted area is also then incorrect. Is the shell area below the operating deck included in the total area? If so, please provide justification.

480.1009 (Page 7-33, second and third paragraphs) Why is 60 lbm/sec used for the flow rate in the second paragraph and 40 lbm/sec in the third paragraph?

480.1010 (Page 7-35, Section 7.7, second paragraph) What is the magnitude of the Biot number for the baffle, and what h is used in the Biot number for this two-sided heat structure? Radiation heat transfer on the outside of the baffle is using the downcomer temperature as the sink temperature. Is it assumed that the shield building and downcomer temperatures are equal?

480.1011 (Page 7-36) Following Equation (158), it is stated that the downcomer operates in opposed mixed convection; however, Equation (158) lists a forced convection heat transfer coefficient for the baffle to the downcomer. Please explain.

480.1012 (Page 7-37) Equation (164) appears to be missing the term "+ $h_{m,n,bf}$" in the numerator of the expression for "b." Please correct or explain.

480.1013 (Page 7-38, Section 7.7.4) In an earlier section, the notation "$\bar{T}$" was used to represent average temperature. In Equation (166), it appears that this notation is now used to represent a/b. Also, is "T" in Equation (166) the same as T_{bf} in Equation (165)? Please clarify in the text.

480.1014 (Page 7-38, Section 7.8) It would seem that the air in the downcomer could be heated by convection from the baffle and, in turn, heat the shield building wall by convection. Justify your conjecture that dry forced convection heat transfer is to the downcomer from the shield building wall.

480.1015 (Pages 7-38 and 7-39) The description of the analysis in Section 7.9 must be improved. First, the terms need to be clearly defined; What is T_{ch}, the chimney concrete average temperature? Later in Section 7.9.4 it is stated that the chimney is treated as a thermally thick structure; so this lumped equation would not apply for the concrete? What is the difference between T_{ch} and $T_{ch,srf}$ and T_{srf}? Equation (167) indicates parallel mass transfer and convection plus series conduction across a film between two chimney temperatures T_{ch} and $T_{ch,srf}$? The π groups in Section 7.9.3, indicate energy transfer between several different temperatures, including $T_{f,ch}$ (which needs to be clearly defined). This carries over to Equation (172) where it is unclear as to what the temperature difference $T_{ri} - T_{f,ch}$ represents. Please explain and include a discussion of what variables are calculated and how they are used in the scaling analysis.

480.1016 (Page 8-1) In Table 8-1 state which heat structures are included for each phase; e.g. do they include above the operating deck plus circulating compartments? How does this compare to what is used in the WGOTHIC model?

480.1017 (Page 8-2, Table 8-2) The anomalous value obtained for $\pi_{c,bf}$ for the long term phase is indicative of a problem in the approach used to combine conductances between different locations into a single conductance. The basic message is that conductances are only meaningful when combined in either series or parallel between the same locations. Other conductances calculated in the same manner as $\pi_{c,bf}$ include $\pi_{c,dex}$ and $\pi_{c,eex}$. Provide values for all π groups (which were calculated using the above approach) leaving out the term with the temperature difference so that any additional anomalies can be identified.

480.1018 (Page 8-2, Table 8-2) Please provide a more detailed explanation of why the pool conductance is extremely low during refill compared to the other phases. The numerator of the pool conductance π group, $\pi_{c,p}$ is evaluated using Equation (105). The only parameters which could cause such a low value appear to be either DP_{stm} or Dr/r. For either DP_{stm} or Dr/r to have a low value, the partial pressure (or the density) of steam in the bulk containment would have to be very close to the value at the pool surface. What assumption is made which gives a low value when there is no break source?

480.1019 (Page 8-3, Section 8.2) The statement regarding external conductance on the evaporating shell at the time of peak containment pressure seems to refer to the values of conductances during the long term phase. This is confusing since there is also a peak pressure phase. Please clarify the discussion.

480.1020 In the tables presented in Section 8, it is stated that a shaded entry indicates a value greater than 10 percent. Please verify the values. For example, $\pi_{m,et}$ in Table 8.3 and $\pi_{p,work,et}$ in Table 8.5, under "Long Term" are -0.02.

480.1021 (Page 9-6) The first paragraph indicates that a simultaneous solution was obtained for eight named variables. Presumably the eight governing equations are the 3 mass conservation equations (173), the three energy conservation equations (175), the momentum equation (176) and the buoyancy equation (179). However, π groups are given in Table 9-1 only for the momentum equation (with a time constant from one of the mass conservation equations), indicating that perhaps a more simplified procedure was used. Please explain in more detail why only one equation is needed to scale the PCS air flow. Also, due to the coupling of the buoyancy pressure drop to the heat transfer, one would expect an iterative solution to be necessary. Was iteration required in the approach used?

480.1022 (Page 9-9, Table 9-1) Please explain why the buoyancy and friction π group values are not equal for the peak pressure and long term phases. According to the statement in the second paragraph of Section 9.3.1, the reference mass flow rate comes from the reference buoyancy term and the reference buoyancy is the steady-state solution of the momentum equation. This statement implies that the π group values should be the same.

480.1023 (Page 10-7, Section 10.1.2) The text describing Figure 10-2 refers to LST data while the figure refers to the STC Flat Plate Test. Which is correct?

480.1024 (Page 10-11, middle paragraph) The Reynolds number at the time of peak containment pressure, 163,000 from Table 9-1, is for the long term phase rather than the peak pressure phase. Please clarify the discussion so that there is no ambiguity as to what number was intended to be used.

480.1025 (Page 10-12, Section 10.1.6) Several terms in Equation (196) have not been defined, or as is the case for σ, are defined in the nomenclature differently than used here. Either here or in the nomenclature all terms should be unambiguously defined.

480.1026 (Page 10-13, Table 10-7) The film Reynolds number for the AP600 upper sidewall given in Table 10-3 is more than a factor of 2 greater than the highest value for either the LST or the water distribution test. An even higher value of 4,000 is given as the upper range for AP600 in Figure 10-3. Justify your statement that the range of AP600 operation is adequately covered by the test data.

480.1027 (Page 10-13, Section 10.1.7) How does the film thickness in the Wisconsin and Chun and Seban data compare to the 0.005-inch thick liquid film assumed in the scaling model?

480.1028 (Page 10-16) In Figure 10-4, clarify the location labeled "above." Is this all heat sinks above the operating deck? Also, please explain the very rapid heat absorption in the core makeup tank (CMT) room and add a curve showing heat rejection to the annulus.

480.1029 (Page 10-17, Section 10.2.1.1) In order to obtain the information for comparison of the π groups inside containment, it was necessary to calculate the state outside the vessel as noted on the bottom of Page 10-17. The scaling of evaporative cooling on the outside of containment is also a high ranked phenomena to which the LST scaling should be applicable, with the buoyancy pressure drop replaced by the forced flow pressure drop. Include an evaluation of the mass and energy π values for the LST air flow path outside containment.

480.1030 (Page 10-18, Section 10.2.1.2) The transient validation of the dP/dT equation is useful to the extent that it shows that the gas compressibility for air is being treated correctly in the scaling equations. The validation against LST steady-state test data in Section 10.2.1.1 shows that the scaling handles the inside containment shell heat transfer in a reasonable way. Ideally, the scaling equations should be integrated and compared to transient scaled test data to validate the entire model. In the case of AP600, such transient test data do not exist. In lieu of this, the staff has previously suggested that Westinghouse integrate the scaling equations for AP600 (as was done in WCAP-14190) to show that reasonable results are obtained. Given that the scaling equations predict a negative rate of pressure change for refill and beyond, as shown in Section 10.0, one need not integrate the scaling equations to conclude that the results will not compare well to WGOTHIC predictions. Westinghouse cites conservatisms in the WGOTHIC model (for example, use of Uchida and biases in shell heat and mass transfer models) as the suspected cause for the differences between the scaling model results and computer code best estimate predictions. Nevertheless, such significant differences raise concerns regarding the value of the scaling study as an indicator of the magnitude and importance of individual processes. In particular, have any of the phenomena been modeled non-conservatively in the scaling analysis?

The rate of pressure change scaling result is counterintuitive. From the π values in Table 10-5, the rate of pressure change at the start of the peak pressure phase is barely increasing, even when heat transfer to the shell is ignored. Neglecting the shell, the total π value on the right side of the equation is 1.03 - 1.02 = 0.01. When the shell is ignored, the AP-600 is similar to an existing plant (with no containment wall heat sink). Intuitively, based upon present plant containment analyses and testing, one would not expect the pressure to increase only during the relatively short blowdown period, and remain essentially constant immediately thereafter, especially when the containment wall heat sink is ignored. For the present generation of large dry containments, analyses show that the pressure turns around only when the sprays are activated. It is difficult to accept that the structural heat sinks alone, with the entire shell ignored, are sufficient to essentially stop the pressure increase.

Westinghouse should convincingly demonstrate that the scaling analysis does not model the heat sinks in a non conservative fashion.

480.1031 (Page 10-21) What is the difference between the π values given in Table 10-10 for AP600 and those given in Table 10-4? Following the convention established in the earlier sections, the last 6 rows of π values in Table 10-10 would generally be negative. To what value does the footnote in Table 10-10 apply?

480.1032 (Page 11-1) Please provide a definition of distortion. This is essential in order to clarify how the evaluations in the third column of Table 11-1 were developed.

480.1033 (Page 11-2) One potential distortion not addressed is the non-prototypical scaled thickness of the shell. This item should also be addressed.

480.1034 (Page 11-4) The LST feature "External Water Flow too High" is evaluated from the viewpoint that a range covering AP600, from no flow to very high flow was tested. The aspect that is not addressed is the larger amount of heat removed by the subcooled liquid in LST. This difference should also be addressed.

480.1035 (Page 11-5) Under "External water flow oscillations," it is stated that the data were evaluated using both the maximum and minimum flow rates. The evaluation does not appear to be in this scaling report. A reference to the evaluation needs to be included.

480.1036 (Page 12-1) The bullet under Item 1 refers to a non-existent Table 8-6. Please correct the reference. Also, considerable quantitative information has been developed which should be used for closure with the PIRT. The cursory statement in Item 2 should be expanded to discuss π values for the high and medium ranked PIRT phenomena.

Apparent Typographical Errors/ Nomenclature Inconsistencies

The following apparent errors need to be addressed or corrected in the final revision of the report.

(Page xii) Second paragraph, third line: "and", the third word from end of the line should be deleted.

(Page xii) The ISTIR and Wulff "were" not "was" used for guidance.

(Page 4-6) In Equation (17), the 1/3 exponent of (n^2/g) should be deleted.

(Page 5-8) In Equation (55), the last term in the first line should be divided by m_{air} and the first term in the second line should be divided by m_{stm}.

(Page 6-7) The term $h_{f,j}$ seems to have been changed to $h_{lf,j}$ between Equations (65) and (67). Are these the same?

(Page 6-8) The term h_j in Equation (68) has been changed to $h_{q,j}$ in the nomenclature section and in later usage, e.g. equation (69).

(Pages 6-8 and 6-9) There is a change in notation between the nomenclature section on Page 6-8 and the second of equations (69). Several dimensionless enthalpies are denoted by h^* in the nomenclature and in the first of equations (69), but as Dh^* in the second of (69) and subsequently. $h^*_{H,j}$ in the nomenclature should be $h^*_{lf,j}$.

(Page 6-9) In the first line of Equation (69), $Dh_{brk,o}$ should be $D_{hg,brk,o}$; h^*_{brk} should be $h^*_{g,brk}$ and the "t" in the denominator of the second term on the right side should be deleted.

(Page 6-9) What is the meaning of the "i" subscript in Equation (71). It is not defined here or in the nomenclature.

(Page 6-9) The sign of the last term in Equation (72), $h_{q,j}A_j(T - T_{lf,j})$, should be positive, not negative.

(Page 6-10) The expression for the reference break gas work term near the end of Section 6.3.2 appears to be missing several "o" subscripts.

(Page 6-12) In Equation (80), it appears that wherever the term $m^*_{g,brk}$ appears in the denominator, it should be deleted.

(Page 7-9) The term $m^*_{flash,d}$ should multiply the right side of the first equation at the top of the page.

(Page 7-9) The superscripts in the middle term of the third of equations (100) should be "*", and not "+".

Enclosure 2

(Page 7-9) Equation (101) should have $A_{d,o}$ and not A_o.

(Page 7-9) An "=" should replace the "+" in equation (102).

(Page 7-14) Equations (110) and (111) contain the term $\pi_{m,p}$. Is this the same as $\pi_{m,evap,p}$ in Equation (108)? If so, perhaps the same nomenclature should be used.

(Page 7-21) If $\pi_{m,j}$ in Equation (125) is the same as $\pi_{m,atm,j}$, it would help to use the same nomenclature in both locations.

(Page 7-21) In Section 7.5.6, Reference 33 is incorrectly cited. Reference 13 should be cited.

(Page 7-23) Figure 7-3, which shows all of the intermediate temperatures between the containment atmosphere and the baffle, is referred to just prior to Equation (130). If T_{srf} used in Equation (130) corresponds to one of these intermediate temperatures, then it would seem appropriate to use the nomenclature from Figure 7-3. This also applies to T_{shx} in equation (134).

(Page 7-25) The $c_{v,sh}$ in the first term of Equation (134) should not be a subscript.

(Pages 7-26 and 7-27) If D_h in Equation (138) is the same as d_h in Equation (140), then shouldn't the same nomenclature be used?

(Page 7-28) In Equation (145) is $\pi_{e,t,j}$ the same as $\pi_{e,it,j}$ in Equation (70)?

(Page 7-28) In the third of equations (146) $h_{g,xf,o}$ should be $h_{q,xf,o}$.

(Page 7-29) On the left side and in the numerator of the first of equations (147) the subscript "g" should be replaced by "q". This same comment applies to Equation (148).

(Page 7-29) In the second of equations (147), $A_{esx,o}$ should be $A_{dsx,o}$ and $T_{xf,o}$ should be $T_{dsx,o}$.

(Page 7-31) In the fourth of equations (152), the first "+" should be replaced by "=".

(Page 7-39) If $T_{ch,srf}$ in Equation (167) is the same as T_{srf} in Equation (168) should not the same nomenclature be used.

(Page 7-39) The "+" superscripts in Equation (168) should be "*".

(Page 10-6) In the first line of Section 10.1.1 is the last "and" extraneous? Also, in the reference to Section 10, what was intended?

(Page 10-19) The value for $(1-\Sigma\pi_{m,j})$ for Test 212.1C does not appear to be correct. Please verify or correct the information.

(Page 11-4) First word of the fourth line, numbers, should be singular.

(Page 11-5) Second paragraph under "External water flow oscillations," the fourth word "were" in the first line should be deleted.

(Page 12-1) In Item 1, Quantitatively is misspelled.

(Page 12-1) Under Item 1, the bullet paragraph refers to Table 8-6. There is no Table 8-6 in the report.

(Page 13-4) The Sherwood number definition should have P_{lm}, not P_{Bm} in the numerator.