March 4, 1997

Mr. Nicholas J. Liparulo, Manager
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Nuclear and Advanced Technology Division
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SUBJECT: AP600 PASSIVE CONTAINMENT COOLING SYSTEM (PCS) AND WGOTHIC COMPUTER CODE REVIEW

Dear Mr. Liparulo:

There are three key reports related to the AP600 PCS and WGOTHIC computer code that are needed to support the Nuclear Regulatory Commission (NRC) staff's licensing review of the PCS and the acceptability of the WGOTHIC computer program for the performance of the DBA analyses. The three reports are WCAP-14783 (scaling), WCAP-14812 (PIRT), and WCAP-14407 (WGOTHIC Application to AP600). The staff has performed reviews and provided comments and requests for additional information on preliminary and draft versions of these reports. These reports must be consistent in scope, content, and terminology, and provide sufficient technical detail to adequately summarize issues. Because there has been difficulty in reaching closure on a number of issues associated with WGOTHIC, two meetings have been scheduled for March 5 and 6, 1997, to discuss the closure path for this review.

In order to facilitate your preparation for the March 5 and 6, 1997, and future meetings on the WGOTHIC computer code, we are providing staff comments on the three key reports, WCAP-14783 (scaling) in Enclosure 1, WCAP-14812 (PIRT) in Enclosure 2, and WCAP-14407 (WGOTHIC Application to AP600).

If you have any questions regarding this matter, you can contact Diane Jackson at (301) 415-8548.

Sincerely,

original signed by:

Theodore R. Quay, Director
Standardization Project Directorate
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Docket No. 52-003

DF03/1

Enclosures:
As Stated

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Docket No. 52-003
AP600

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Comments on WCAP-14783

The following are the staff's recommendations for the final scaling report:

The scaling study, which is expected to be submitted in late-February or early-March 1997, must be sufficiently detailed and complete so that it demonstrates the following:

- The WGOTHIC code is applicable at the scale of the AP600, consistent with the requirements of 10 CFR 52.47(2)(i)(A)(1)-(3). This should be a stated objective of the scaling analysis.
- Calculated values of π-groups support the PIRT rankings given in WCAP-14811/14812; values (mass, volume, area, etc.) used to evaluate the π-groups are consistent between the scaling report (WCAP-14783), the PIRT report (WCAP-14811/14812) and the DBA EM model in Section 4 of WCAP-14407.
- Sufficient information is included to allow independent verification of the scaling equations and the calculated values of π-groups.

The draft scaling report submitted by letter NSD-NRC-96-4790, dated July 8, 1996, "Retransmittal: Scaling Analysis for AP600 Containment Pressure During Design Basis Accidents," (except as noted in discussion items previously provided to Westinghouse) contains sufficient detail regarding the derivation of the scaling equations. The final report needs to contain the same level of detail. Due to the need for revisions of some equations, verification of numerical values for π-groups was not performed. When the scaling report is submitted, it must include numerical values of input parameters, so that the calculation of π-group numerical values can be verified.

The scaling study must include the numerical values of π-groups for the AP600, as well as for relevant scaled test facilities, and sufficient justification for the applicability of the WGOTHIC models at the AP600 scale. The justification for application of WGOTHIC to AP600 should be based on similitude and show that the range of test data supporting the WGOTHIC models includes the range for AP600 application.

Enclosure 1

Comments on WCAP-14811/14812

WCAP-14811, "Accident Specification and Phenomena Evaluation for AP600 Containment Cooling System," Revision 0, December 1996, was submitted to the staff by Westinghouse letter NSD-NRC-96-4921, dated December 19, 1996, as a proprietary report. Westinghouse later determined that this report did not contain any proprietary information and resubmitted it as non-proprietary, as WCAP-14812 by Westinghouse letter NSD-NRC-97-4971, dated February 3, 1997. Westinghouse stated that the report content did not change. The following are the staff's recommendations for WCAP-14812, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System":

The staff believes that WCAP-14812 should serve as the closure vehicle. When finalized, the WCAP should provide the specific information concerning, as appropriate, (1) how scaling (WCAP-14783) supports the rank for each PIRT phenomena or parameter, (2) how testing and separate effects experiments support the rank for each PIRT phenomena or parameter, (3) what are the first principles and what type of engineering judgement provide the basis to support the rank for each PIRT phenomena or parameter, and (4) how the WGOTHIC DBA EM (WCAP-14407) addresses each phenomena or parameter.

The present content of Section 4.4, "Ranking of Phenomena Listed in the PIRT", is not sufficiently detailed to complete the technical review. The content needs to be revised and expanded to include technical justification for the rankings.

With regard to the use of scaling as a basis for establishing PIRT rankings, general statements such as the following did not establish an adequate technical basis:

> "Scaling shows that the mass and energy releases from the break source are the driving forces for the containment response for both LOCA and MSLB events, ..., therefore these parameters were all ranked High."

> "At 24 hours energy scaling indicates that the steel is a small heat source." (Note: 24 hours is not used as a time phase in WCAP-14811/14812, it has been replaced by "Long Term".)

In each case where information from the scaling study is used as the basis for establishing a PIRT rank, the specific π-groups involved in the justification and their numerical values must be cited, as was done in the February 12, 1996, draft PIRT report (letter NSD-NRC-96-4643, "Accident Specification and Phenomena Evaluation for AP600 Passive Containment Cooling System").

A general reference to a test report or data analysis report without specifically identifying the applicable information, as is done in the present report, is unacceptable for a technical basis. Where test data or test data analysis information is used as the basis for a PIRT ranking, the test case(s) and/or specific data analysis which supports the argument must be cited and summarized. An explanation of how the data or data analysis supports the ranking must be included.

Enclosure 2

Examples of adequate closure statements would contain the following information:

1) For the scaling analysis: The scaling report, in Section X.Y "(Parameter) Pi Group Values", shows that $\pi_{i,i}$ for the (phenomena or parameter) group has a value of x.xx which support (or confirms) a (high, medium or low) rank.

2) For test results: (a) In the Large Scale Test (LST) test xxx.y, which is representative of (LOCA or MSLB), measurements of (parameter) shows (or confirms) that (phenomena or parameter) is ranked as (high, medium or low). (b) In WCAP-nnnnn Section X.Y "(Parameter)," data from (experiments a, b, c, etc) for (dimensionless number or physical parameter) are shown to cover the range of (dimensionless number or physical parameter) for the AP600.

3) For first principles: If the perfect gas law is assumed then it can be shown that the (phenomena or parameter) should be ranked (high, medium or low). (Provide or reference any detailed calculation which were performed with the assumption.)

4) For engineering judgement: Discuss the field of expertise and related process, such as heat transfer or mass transfer as applied to similar situations but not necessarily containment or nuclear power plants.

5) For DBA EM modeling: To account for the (high, medium or low) ranking of (phenomena or parameter), (a) the input value for (parameter) is set to a value of (value) as shown in Section 4.Y of WCAP-14407, or (b) (parameter) is conservatively accounted by (reducing, increasing, omitting) as discussed in Section 4.Y of WCAP-14407.

6) For <u>W</u>GOTHIC sensitivity analyses: To confirm the ranking, a sensitivity analyses was performed and is provided in Section X.Y of WCAP-14407 which shows that (reducing, increasing, omitting) results is a conservative (or bounding) analysis.

Comments on WCAP-14407

The following are the staff's recommendations for WCAP-14407, "WGOTHIC Application to AP600":

Section 2 of WCAP-14407 is not consistent with the PIRT in WCAP-14811/14812, and the scaling study in WCAP-14783. These reports need to be consistent in terminology, organization of phenomena, and PIRT rankings.

In Section 4, modeling assumptions and input values or parameters which are related to the PIRT are not clearly identified. For example: (a) To account for mixing which is ranked as high, the break location is placed high in the above deck region for the MSLB. This conservatively addresses the mixing issue. (b) Mass transfer is ranked high and a value of x.xx is used as a multiplier on the mass transfer coefficient to conservative bound the available experimental data as shown in Section X.Y of WCAP-nnnnn.

In addition, the following calculational issues should be addressed (note that some of these issues have been previously identified as RAIs).

1) For each section of WCAP-14407, please identify all computational results which have been obtained through the strict application of the AP600 DBA EM specified in Section 4. If results were obtained using models different from the AP600 EM, identify each of the model differences. A justification for the use of the alternate model and an evaluation of the impact on the calculational results needs to be provided. If there is a concern that the difference could impact the current calculational results, additional studies with the DBA EM should be performed to reach closure.

2) For the DBA-LOCA, a comparison of results from SATAN and WCOBRA/TRAC computer code computations for break mass flow and energy rates, and the rates used as inputs for the AP600 containment analysis needs to be provided.

3) Provide a sensitivity study which evaluates the containment pressure response of increasing the steel jacket-to-air gap thicknesses up to 0.125 inches. This study should cover the 24 hour period. Relevant construction data to justify the use of values less than 0.125 inches for the steel jacket-to-air gap thicknesses needs to be provided. (Current value is 0.005 inches.)

4) Justify the selected constant values for the quantities:

   a) frictional length = 1 ft;
   b) forward loss coefficient = 1.5; and
   c) reverse loss coefficient = 1.5,

   for below operating deck compartments for DBA-LOCA for the:

   a) blowdown phase (0 to ~30 sec);

b) transition phase (30 to ~1500 sec); and
c) long-term (1500 sec to ~24 hours).

Also, justify the values for the MSLB.

5) Justify the selected constant values for the quantities:

a) frictional length = 1 ft (except of outer quarter annuli);
b) forward loss coefficient = 0; and
c) reverse loss coefficient = 0,

for above operating deck compartments for DBA-LOCA for the:

a) blowdown phase (0 to ~30 sec);
b) transition phase (30 to ~1500 sec); and
c) long-term (1500 sec to ~24 hours).

Also, show that the same values hold for the MSLB.

6) For DBA-LOCA, provide superpositions of temperature histories over the total time span of interest for:

a) break compartment;
b) equivalent compartment in opposite SG-compartments;
c) midway in affected SG-compartment;
d) top of affected SG-compartment;
e) affected quarter inner dome volume; and
f) affected quarter outer dome volume.

7) For DBA-LOCA, provide superpositions of steam concentrations over the total time span of interest for:

a) break compartment;
b) equivalent compartment in opposite steam generator-compartments;
c) midway in affected SG-compartment;
d) top of affected SG-compartment;
e) affected quarter inner dome volume; and
f) affected quarter outer dome volume.

8) For DBA-LOCA and the relevant affected dome quarter, provide superpositions of temperature histories for all relevant quantities of a clime (e.g. condensate, inside steel surface, outside steel surface, film temperature, air temperature) for:

a) top position;
b) upper cylindrical part; and
c) lower cylindrical part.

9) Provide the information listed under (8) for the opposite quarter.

10) Show axial temperature distributions of the most important clime element stacks for relevant instances in time (30 sec, 90 sec, 1500 sec, etc.).

11) Provide axial atmospheric temperature distributions in the center of the AP600 containment over the height of the control cylindrical room, respective quarter inner and outer dome compartments for relevant instances in time (30 sec, 90 sec, 1500 sec. etc.).

12) Provide the transient liquid level histories for the below operating deck compartments.

13) Provide the transient histories of energy transferred into:

    a) heat sinks below operating deck;
    b) heat sinks above operating;
    c) to containment atmosphere;
    d) over steel shell;
    e) to PCS coolant;
    f) rising air flow;
    g) to baffle; and
    h) shield building.

14) Show transient histories of accumulated condensate in below-operating deck compartments.

15) Show transient histories of accumulated condensate above the operating deck.

16) Show superpositions of hydrogen concentrations in the break compartment and upper most dome region over the total time of interest.

17) Show comparisons of temperatures, steam concentrations, "velocities" in volumes at the same height of the affected and unaffected SG, which show global circulation patterns over the total time of interest.

The status of the revision to Section 9 of WCAP-14407 is uncertain. The current discussion on mixing and stratification is based on arguments which seems to apply to a distributed-parameter type model where momentum is treated. There are concerns with the information being used to support the lumped-parameter type model for licensing.

Because of the unique importance of mixing and stratification issues to the analysis of the MSLB event, information regarding potential steam line break positions and related containment response should be provided.

18) Identify any differences between the WGOTHIC AP600 DBA EM and the MSLB model which has been used for bounding computations. Provide information about the heat sink assumptions used for the Core Makeup Tanks (CMT)-positioned MSLB calculations.

19) Provide computational results, and comparisons, from the WGOTHIC AP600 DBA EM for MSLB at two representative break positions (top of the steam generator and vicinity of operating deck) for:

    a) containment pressure;
    b) axial temperature distribution inside containment;
    c) axial steam concentration distribution;
    d) representative temperatures along major flow(s) path below operating deck; and
    e) representative steam concentrations along major flow(s) path below operating deck.

20) Justify the assumption that high Froude number steam release jets of short duration mix the atmosphere in the regions above and below the jet source elevation. It could be helpful to provide comparisons between computational results of distributed-parameter and lumped-parameter network WGOTHIC calculations which demonstrate that the lumped parameter treatment of jet and plume characteristics is conservative with regard to the predicted containment pressure history. Compare these calculations to LST test 222.4 and the LST test results which span the Froude number range experimentally examined. Show that the lumped parameter network model has a conservative bias as stated in Section 9 of WCAP-14407.

21) The LST data examined covers a very limited range of Froude numbers to characterize the potential AP600 behavior. Provide evidence that the same bias holds for Froude numbers expected in the AP600, which are by two orders higher and by two orders lower. Provide experimental and/or computational evidence for the behavior of very high and very low Froude number releases and associated mixing characteristics.

22) Show the WGOTHIC predicted entrainment as a function of time for the complete range of Froude numbers covering the AP600 MSLB-conditions. Show results for the time period required for a highly energetic steam jet to reach the dome apex. Compare experimental data to WGOTHIC calculated entrainment rates for momentum driven jets and buoyancy-driven plumes in order to demonstrate under what conditions mixing is most effective.

23) Provide information on how "numerical mixing in lumped-parameter networks" contributes to the bias or counteracts a conservative bias.

24) The relatively small mass flow rate into compartments below the operating deck may be an artifact of the lumped-parameter approach and insufficient axial nodalization of the compartments below the operating deck. Provide LST experimental data for the mass flows entering the below-operating deck compartments as a function of time for the highest and lowest MSLB elevations above the operating deck. Compare these values to WGOTHIC computed results.

25) It could be helpful to provide comparisons between a distributed-parameter and a lumped-parameter network WGOTHIC computation which demonstrates that the lumped-parameter network calculations are always bounding for any break location, elevation, and discharge orientation (e.g., CMT-room, low positioned break and high positioned break of steam pipe, vertical or horizontal discharge).

26) Provide information, or a reference, which shows that a MSLB-break size of 1.388 ft^2 at 30 percent power is bounding under all circumstances and list all parameter changes which were examined to reach this conclusion.

27) Show the effect which the asymmetric MSLB-location has on:

   a) the containment pressure history;
   b) temperature distribution above the operating deck;
   c) heat sink utilization; and
   d) energy removal at the steel outside surface over its axial height.

   Provide these results for the 24 hour time period for all three break elevations.

28) Show that the selected bounding approach also meets the bounding requirements for determining conservative temperatures.

The following concerns need to be addressed for the LOCA:

29) Describe the treatment of the break liquid phase in the WGOTHIC model for AP600. Demonstrate that this model is conservative with regard to containment pressure, mass of condensate collected in the in-containment refueling water storage tank (IRWST), the sumps, the dead end compartments, and the predicted condensate at the inside surface of the steel shell.

30) Show the effects of the release of hydrogen (Ref: WCAP-14811/14812) on heat sinks and PCS cooling in the presence of non-condensable gases and demonstrate the conservatism of the model chosen for the WGOTHIC AP600 DBA EM. Present figures which show the following:

   a) axial steam concentration distribution;
   b) axial air concentration distribution;
   c) axial hydrogen concentration distribution; and
   d) axial distribution of condensate at inside steel shell surface over the height of the quarter outer dome nodes.

31) Demonstrate the validity of the WGOTHIC treatment of buoyancy forces for the lumped-parameter network AP600 DBA EM and show what time periods during the LOCA and MSLB events these forces dominate.

32) Provide information how the selection of control volumes in the specific containment regions benefitted from the mixing considerations presented in Section 9.3.1.

33) Provide information how jet momentum considerations can affect the nodalization scheme chosen for the lumped-parameter network AP600 DBA EM. Lumped-parameter models completely dissipates momentum in each control volume.

34) Show how CMT-specific entrainment considerations are accounted for in a lumped-parameter model, which has no compartment specific phenomenological models for jet and plume phenomena.

35) Provide comparisons between data and computational results from the WGOTHIC AP600 DBA EM which demonstrate that the lumped-parameter network model correctly predicts large-scale circulations throughout the containment. Consider that circulation may be affected by increasing liquid levels in the compartments below operating deck.

36) Show how stratification effects are superimposed on the large-scale circulation pattern and compare this result with experimental data.

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