Docket File

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

March 10, 1997

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

SUBJECT: FOLLOWON QUESTIONS REGARDING THE AP600 DIFFUSION FLAME REPORT

Dear Mr. Liparulo:

As a result of its review of the June 1992 application for design certification of the AP600, the staff has determined that it needs additional information. Specifically, a set of questions were faxed to Westinghouse concerning the AP600 diffusion flame report. These questions are listed in Enclosure 1. A telcon was held on February 7, 1997, between the staff and Westinghouse to discuss the questions in Enclosure 1. As a result of this telcon, the questions were focused and it was decided to turn them into formal requests for additional information (RAI). The questions in Enclosure 2 have been assigned unique numbers and have been slightly modified. Therefore, it is requested that Westinghouse formally respond to the questions in Enclosure 2. Please note that question 8 of Enclosure 1 was not turned into an RAI because during the telcon on February 7, 1997, Westinghouse referred the staff to Figure A-13 of the diffusion flame report which addressed the staff's concern.

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 followon questions 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.

If you have any questions regarding this matter, you may contact me at (301) 415-1132.

Sincerely,

original signed by:

Joseph M. Sebrosky, Project Manager
Standardization Project Directorate
Division of Reactor Program Management
Office of Nuclear Reactor Regulation

Docket No. 52-003

Enclosure: As stated

cc w/enclosure:
See next page

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DOCUMENT NAME: A: FLAME.RAI

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Westinghouse Electric Corporation

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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The following comments and questions are in regards to the Westinghouse Electric Corporation report "Assessment of the Potential Impact of Diffusion Flames on the AP600 Containment Wall and Penetrations, AP600 Doc # PRA GSR 004, Nov. 1996".

1. The report uses correlations to determine the flame characteristics. Please provide justification for the use of these correlations and address the following points:

   a. The report uses correlations applicable for an isolated plume. The hydrogen burn in the AP600 is not a single unconfined fire. The analysis predicts a linear series of approximately 16 flames that are closely spaced (spacing on the order of the flame diameter). Thus, the neighboring flames will compete for the same air, and the flow pattern will be altered. Potentially this altered flow pattern will cause the flames to be taller and hotter.

   b. Each flame is approximately 1 meter from a solid containment wall. Thus, the flames are not in an unconfined space. Little air is available to enter the flame between the plume and the wall. The incoming momentum of the air entering from the direction opposite to the wall will cause the plume to become attached to the wall. This mechanism also makes the flame taller and hotter. Does the analysis assumes the flame will attach to the wall?

   c. The correlations are only for vertical exit planes, and the current AP600 IRWST vent geometry includes a horizontal exit.

2. It appears that the report assumes that the hydrogen fuel is distributed between three sets of vents (16 IRWST sparger side vents, 5 IRWST PRHR Hx side vents and 5 vents of 24 inch pipe). The model for the flow resistances that effect the distribution for the hydrogen is not clearly described. Also, the model implicitly assumes that the flow is equally distributed between each of the individual vents within each set. The report has not demonstrated that this partitioning is accurate or conservative.

3. The report does not give much detail on the heat transfer calculations performed. Only the final results are provided. However, the report indicates that the heat flux is entirely radiative from the flame to the containment wall. Independent calculations indicate that the temperatures obtained are reasonable for a radiative source, however, the items listed above may invalidate the radiative assumption. The flame may be hotter than assumed, and the flame may become attached to the wall yielding a significant convective heat flux.

4. There is little design detail provided in the report. The most important items missing are:

   a. Distance between the IWRST sparger side vents.

b. The report gives no information on the availability of air behind IWRST vents. Please clarify the geometry of the open volume behind the vents and below the operating deck (see Figure 11 of the report). How much air is available to feed the diffusion flame between the IWRST vents and the containment wall?

c. The detailed design of the various vents to the IWRST. The report does not give design details (existence of elbows or flappers, dimensions) and is not clear if these vents will release liquid or gas from the IRWST head space. The information must be provided for:

   1. IWRST sparger side normal vents,
   2. IWRST sparger side 24 inch pipe vents,
   3. IWRST PRHR Hx side vents,
   4. Refueling canal vents and
   5. Reverse flow vents

d. The pressure required to open the vents for full and partial flow of the vents.

e. The diameter of the containment cylinder, the baffle, and the ID of the concrete shield building. The following three dimensions were obtained from older Westinghouse AP600 reports: 130 ft, 132 ft, 139 ft. Are these dimensions correct?

f. The minimum head space (distance from the IWRST ceiling to the liquid surface) in the IWRST:

   1. without liquid swell due to sparger operation and
   2. with liquid swell due to sparger operation

5. Numerous errors exist in the text.

   a. The report estimates that the maximum temperature of the diffusion flame will be approximately 900 K above ambient. This is equivalent to 1620 F above ambient (not 1160 F as reported on page 25).

   b. Equation 6.1 has two errors (910 should be 9.10 and tau_zero should be tau_infinity).

6. The typical calculations provided seem to use 2 Kg/s total flow of a fuel mixture of 5 percent hydrogen and 95 percent steam. However, the data plots show that the maximum hydrogen concentration can approach 85 percent. What is the justification for the assumption used?

7. Note #3 on Table 2 states that two of the vents "are being reserved for venting from the containment back into the IRWST to prevent over pressurization of the IRWST during a LOCA or SLB and as a result will not be available for venting out of the IRWST." It is not clear that allowing venting into the IRWST will prevent over pressurization of the IRWST.

8. Page 14 states, "The existence of the flappers on each of the IRWST vent paths to prevent mixing with the air in the rest of the containment regions also impacts the diffusion flame assessment." However, the report does not specify what is the impact in the assessment. Moreover, it is unclear if the mixing can be prevented since the flappers in two of the vents have reverse orientation from the rest. How this assumption was used in the analysis?

9. The thermal limits on the containment vessel are calculated based on a reduction in the modules of elasticity of the structural steel. The modules of elasticity is a slope, and not a yield stress (or strength as implied by the caption given for Figure 13). To equate changes in the modules of elasticity to strength limits one must assume an elastic process up to failure and also assume that the strain to failure is equal at all temperatures. It would be better to use the reduction in the actual yield stress due to temperature increases. This is somewhat difficult due to the creep behavior that occurs at high temperatures, but classic handbooks (e.g. Engineer's Guide to High Temperature Materials, F.J. Clauss, Addison Wesley, 1969) give plots of "Stress to cause rupture in 10,000 hours," which would be a conservative measure to use in developing strength limits. How were these details were included in the Westinghouse analysis?

## FOLLOWON QUESTIONS CONCERNING THE AP600 DIFFUSION FLAME REPORT

The following questions are in regards to the Westinghouse Electric Corporation report "Assessment of the Potential Impact of Diffusion Flames on the AP600 Containment Wall and Penetrations, AP600 Doc # PRA GSR 004, Nov. 1996".

480.947 The report uses correlations to determine the flame characteristics which may not be applicable to the AP600 application. For example, the correlation for flame temperature is derived from calculations of a round heater on a horizontal floor, and thus contains no combustion physics (heats of formation, oxygen diffusion, etc.). Therefore, use of this correlation, in particular, must be justified when it is applied outside of its accepted range (vertical low velocity exits of hydrocarbon fuels in an unconfined space). Please provide justification for the use of flame correlations and address the following points:

a. The report uses correlations applicable for an isolated plume. The hydrogen burn in the AP600 is not a single unconfined fire. The analysis predicts a linear series of approximately 16 flames that are closely spaced (spacing on the order of the flame diameter). Thus, the neighboring flames will compete for the same air, and the flow pattern will be altered. Potentially, this altered flow pattern will cause the flames to be taller and hotter.

b. Each flame is approximately 1 meter from a solid containment wall. Thus, the flames are not in an unconfined space. Little air is available to enter the flame between the plume and the wall. The incoming momentum of the air entering from the direction opposite to the wall will cause the plume to become attached to the wall. This mechanism also makes the flame taller and hotter. Does the analysis assume the flame will attach to the wall?

c. The correlations are only for vertical exit planes, and the current AP600 IRWST vent geometry includes a horizontal exit.

480.948 It appears that the report assumes that the hydrogen fuel is distributed between three sets of vents (16 IRWST sparger side vents, 5 IRWST PRHR Hx side vents, and 5 vents of 24 inch pipe). The model for the flow resistances that effect the distribution for the hydrogen is not clearly described. Also, the model implicitly assumes that the flow is equally distributed between each of the individual vents within each set. Provide further justification for the flow resistances and the assumption that the flow is equally distributed.

Enclosure 2

480.949 Further detail on the heat transfer calculations performed is needed for the staff to complete its review. Only the final results are provided. The report (and a supplementary fax, dated February 6, 1997) indicates that the heat flux is both convective and radiative from the flame to the containment wall. Independent calculations indicate that the temperatures obtained are reasonable for a radiative source only given the assumed flame temperatures. However, the items listed above may invalidate the flame temperature used, and a convective flux for an attached flame should yield a significant convective heat flux. Details and justifications for the heat transfer parameters (view factors, convection coefficient, etc.) should be provided.

480.950 Further design detail is needed. The following items are needed in order for the staff to complete its review of the report:

a. Distance between the IWRST sparger side vents.

b. The report gives no information on the availability of air behind IWRST vents. Please clarify the geometry of the open volume behind the vents and below the operating deck (see Figure 11 of the report). How much air is available to feed the diffusion flame between the IWRST vents and the containment wall?

c. The detailed design of the various vents to the IWRST. The report does not give design details (existence of elbows or flappers, dimensions) and is not clear if these vents will release liquid or gas from the IRWST head space. The information must be provided for:

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f. The minimum head space (distance from the IWRST ceiling to the liquid surface) in the IWRST:

   1. without liquid swell due to sparger operation and
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480.951 The following discrepancies were identified in the text:

a. The report estimates that the maximum temperature of the diffusion flame will be approximately 900 °K above ambient. This is equivalent to 1620 °F above ambient (not 1160 °F as reported on page 25).

b. Equation 6.1 has two errors (910 should be 9.10 and tau_zero should be tau_infinity).

Please correct these values, or justify them.

480.952 The typical calculations provided seem to use 2 Kg/s total flow of a fuel mixture of 5 percent hydrogen and 95 percent steam. However, the data plots show that the maximum hydrogen concentration can approach 85 percent. What is the justification for the assumption used?

480.953 Note #3 on Table 2 states that two of the vents "are being reserved for venting from the containment back into the IRWST to prevent over-pressurization of the IRWST during a LOCA or SLB and as a result will not be available for venting out of the IRWST." It is not clear that allowing venting into the IRWST will prevent over-pressurization of the IRWST. Perhaps the authors meant to prevent under-pressurization. Please clarify.

480.954 The thermal limits on the containment vessel are calculated based on a reduction in the modules of elasticity of the structural steel. The modules of elasticity is a slope, and not a yield stress (or strength as implied by the caption given for Figure 13). To equate changes in the modules of elasticity to strength limits one must assume an elastic process up to failure and also assume that the strain to failure is equal at all temperatures. Why wasn't the reduction in the actual yield stress due to temperature increases used? Classic handbooks (e.g. Engineer's Guide to High Temperature... Wesley, 1969) give plots of "Stress to cause rupture... in 10,000 hours," which may be more appropriate in developing strength limits.