52-003

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

September 14, 1995

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

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION (RAI) RELATED TO THE AP600 PROBABILISTIC RISK ASSESSMENT (PRA)

Dear Mr. Liparulo:

Enclosed are the Nuclear Regulatory Commission's (NRC) staff comments on Chapter 42 of the AP600 PRA. These questions supersede Enclosure 2 of the NRC letter to Westinghouse dated August 4, 1995, under the same subject header. You are requested to provide a response to these questions and comments within thirty days of receipt of this letter.

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 20 CFR 2.790, this letter will be placed in the NRC Public Document Room.

These followon questions affect nine or fewer respondents, and therefore this request is not subjected to review by the Office of Management and Budget under P.L. 96-511.

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

Enclosure:
As stated

cc w/enclosure:
See next page

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Mr. Nicholas J. Liparulo
Westinghouse Electric Corporation

Docket No. 52-003
AP600

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For AP600 Containment CCFP Calculations

1. In Chapter 42 of PRA SSAR, Revision 4, the mean failure pressure is mentioned for each failure mode. As stated in DSER, the staff recommended the best estimate pressure be median for containment CCFP calculation. (If lognormal distribution is used, the mean is median times $\exp(\beta^2/2)$ where β is logarithmic standard deviation.) For the failure pressure estimates, the staff is not in a position to accept the 32 percent increase using both von Mises criterion and mean yield strength of SA537 Class 2 material. See Open Items 3.8.2.4-19 and 19.2.6.2-3.

   - A comparison between experimental and theoretical yield stresses in Engineering Design, Faupel, J.H., pp. 249-258, John Wiley & Sons, 1964 shows that the von Mises yield criterion does not always give a 15 percent higher yield stress than that obtained from the maximum shear stress criterion,

   - The material test data uses only 122 specimen and they are neither exactly the same as the SA 537, Class 2 material nor as-built material,

   - In "Comparisons of Analytical and Experimental Results from Pressurization of a 1:8 - Scale Steel Containment Model," Clauss, D.B. and Horschell, D.S., Proceedings 8th Intl. Conf. on SMiRT, August 19 through 23, 1985, and NUREG/CR-4209, the measured yield pressure was reported 15 percent less than that predicted yield pressure (r = 84", t = 0.197", σ_y = 57.1 ksi, $P = \sigma_y t/r$ = 134 psig) using MARC FEM code with large displacement, nonlinear material property obtained from standard uniaxial tensile tests (test coupons were machined from remnants and cutouts for the penetrations), and von Mises yield criterion due to (1) strain rate effects (5 percent reduction), (2) Bauschinger effect (5 to 10 percent reduction) referring to the phenomenon whereby the yield stress in tension or compression is reduced if the material has been previously yielded in the opposite sense (when the plates comprising the cylinder were rolled into the cylindrical shape, the internal surface underwent compressive yielding and internal pressurization results in tensile yielding in the cylinder), and (3) difficulties in applying uniaxial data to multiaxial strain states,

   - From an American Iron and Steel Institute (AISI) survey of test results for thousands of individual product samples, it has been found that strength levels vary as much as 20 percent from the certified material test reports (CMTR) test values. It has been the staff's position that minimum specified strength values (e.g., ASME Code minimum strength values) should be used as the basis for allowable stresses as described in the letter from G. Bagchi and C. Cheng to J. Stolz, Subject: Review of Oyster Creek Drywell Containment Structural Integrity, dated June 14, 1990.

Enclosure

2. In Section 42.2, is lognormal distribution applicable for the 16-ft and 25-ft equipment hatches? Due to their convexity, these are under compression when subjected to containment internal pressure as mentioned, further justification is necessary for these equipment hatches.

3. In Section 42.3.1, Ref. 42-1 did not provide data showing that the actual yield strength of containment construction materials could be 12 to 22 percent higher than the specified minimum material strength. The range is 2.5 to 22 percent in Table 1. Also, there is no data for SA537, Class 2 material in Reference 42-1.

4. In Section 42.4, provide uncertainties for geometric properties (as-built condition) and residual stress for buckling of knuckle area and equipment hatch covers. Imperfection for internal pressure is insensitive, however, for external pressure, it should be significant. (from N-284, capacity reduction factor is considered for imperfection and plasticity of nonlinear material properties.)

5. In Section 42.4.1, how is the Coefficient of Variation (COV) of 0.1 derived from Reference 42-1? The Table 4 of Reference 42-1 shows only the thickness of 1-1/4" thickness (mean = 1.277", σ = 0.012", COV = 0.01) and it assumes normal distribution, not lognormal distribution. Also, this COV of 0.01 represents the uncertainty for geometric properties, not modeling error. The Reference 42-1 shows the modeling error COV of 0.144 from $(0.12^2 + 0.08^2)^{1/2}$ in Table 7. The COV for all practical purposes of modeling error which should include nonsymmetric features such as penetrations and other reinforced openings, longitudinal stringers, etc. as well as circumferential variations in thickness, ring and stringer sizes, amount of reinforcing steel, and shell imperfection is 0.12 (Reference 42-2). The staff believes that the use of the COV of 0.1 results in unconservative CCFP calculation. See Open Items 3.8.2.4-21 and 19.2.6.3-1.

6. In Section 42.4.2, provide mean (median) failure pressures with modeling and material uncertainties for crown yield, knuckle area yield, and knuckle area buckling. Imperfection uncertainty is insignificant due to internal pressure buckling (See N-284).

   How is 192 psig derived in knuckle area? Is it 146*1.15*1.15?

   How is 144 psig derived for ellipsoidal head buckling failure mode in Table 42-1? It is not given in SSAR. Is it derived from 174 x 138/166?

   For the ellipsoidal head, there are two possible failure modes, i.e., asymmetric buckling (P_{cr}) and plastic collapse (P_c). Therefore, the plastic collapse pressure information should be considered in SSAR.

7. In Section 42.4.3, Westinghouse increases 50 percent critical pressure for the best estimate failure pressure based on N-284 curve which was derived from lower bound of tests. However, there was only one test performed for AP600 containment configuration (M_i = 14.5). Therefore, it

is believed that 50 percent curve from tests might be appropriate use for AP600 containment. (N-284 does not provide 50 percent and upper bound curves.) Are test data in N-284 applicable to AP600? They seem to be stiffened spheres.

Also, in NUREG/CR-4209 and -4137, equipment hatch has critical pressure of 3,000 psig and the predicted response of the cover and tensioning ring was elastic up to 360 psig. In this case, only up to 12 percent of critical pressure is elastic. After that, equipment hatch cover will experience plastic deformation. Therefore, Westinghouse's claim that the failure pressure is 150 percent of critical pressure is questionable. See Open Items 3.8.2.4-26 and 19.2.6.3-6.

Equipments hatches are subjected to external pressure, not internal pressure.

8. In Section 42.5, provide the sample CCFP calculations for head at 100 psig. You have constructed the containment failure probability distribution for a particular failure mode by first developing the failure distribution assuming only random error and then developing another distribution assuming only subjective error. The staff believes this method may not be conservative in comparison with the combination of random and subjective errors ($\beta_c^2 = \beta_{material}^2 + \beta_{modelling}^2$) in the left tail region.

9. In Section 42.6, what is the definition of mean internal pressure? Should it be median pressure? See Open Items 3.8.2.4-27 and 19.2.6.3-7.

10. In Table 42-1, does "Structural" under COV heading imply "Material"?

11. In Table 42-2, 50 percent failure pressure for head seems to be around 156 psig. Where does this pressure come from?

12. In Section 42.4, coefficient of variation, not coefficient of variance, should be used.

13. In SSAR Subsection 3.8.2.4.2.5, Electrical Penetration Assemblies (EPAs) to be used will be one of those tested by Sandia in NUREG/CR-5334:

    D.G. O'Brien: 182.8°C (361°F) and 1,068.7 kPa (155 psia) for 10 days,
    Westinghouse: 204.4°C (400°F) and 517.1 kPa (75 psia) for 10 days,
    Conax: 371.1°C (700°F) and 930.8 kPa (135 psia) for 10 days

    If Westinghouse EPAs will be used for AP600, they do not satisfy ASME Service Level C limits (90 psig at 400°F). Also, in fragility curve, the dominant failure mode is cylindrical shell with 138 psig at 400°F. Therefore, if they are used, they control the whole design both in deterministic and probabilistic. The fragility curve for EPAs should be provided.

14. In Section 42.4, if the bellow capacity is 90 psig at 400°F, what is probability of failure beyond this pressure? Westinghouse should provide the mean (or median) failure pressure, and uncertainties of geometric properties, modeling, and material for complete CCFP calculations.

15. In Section 3.8.2.4.2.2, the maximum deflection at crown is 15.9" at 174 psig and corresponding strain is 2.5 percent. Therefore, radius is 15.9/0.025 = 636". Where does this radius come from? The radius, R_s, is 1,347.5".