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Standardization Project Directorate
Office of Nuclear Reactor Regulation
Mail Stop 11 H3
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
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RE: AP600 Probabilistic Risk Assessment Review Issues -- Frequency of Steam Generator Tube Rupture and Reactor Vessel Rupture Initiating Events, and Seismic Core Damage Frequency

Dear Mr. Hasselberg.

Westinghouse Electric Corporation recently (25 June 1992) submitted an application for Final Design Approval and Design Certification the AP600 PWR standard plant design. Two key parts of the AP600 application are the Standard Safety Analysis Report (SSAR) and the Probabilistic Risk Assessment (PRA).

An important selling point (both commercially and in terms of public opinion) and design goal for the AP600 is a frequency of one in a million per year or less for exceedence of a 25 Rem effective dose equivalent at the site boundary within 24 hours without any emergency protective action. The purpose of this letter is to raise three issues in this regard for the NRC's review of the AP600 Probabilistic Risk Assessment -- the frequency of steam generator tube rupture (SGTR) accidents, the frequency of reactor vessel rupture accidents, and the frequency of accidents arising from earthquakes (seismic risk).

SGTR Initiating Event Frequency

The AP600 design is what I would characterize as "semi-passive" in nature. Some safety functions still require successful performance of active components in order to assure safety, while other components are more passive in nature. It would be reasonable, in my estimation, to expect that AP600 could demonstrate superior performance for most accident scenario types when compared with conventional Westinghouse PWRs, which rely almost entirely on safety systems with active components.

Westinghouse claims that the AP600 PRA study supports an analyzed frequency of a 25-Rem site boundary dose of 3×10^{-6} per reactor-year for all events, in comparison to the 1×10^{-6} per reactor-year goal. 1/ In order for Westinghouse to sustain this claim, Westinghouse must be able to demonstrate that the frequency of SGTR core melt accidents is less than 3×10^{-8} per reactor-year since it is apparent that the site boundary dose from an SGTR core melt accident

1/ Westinghouse, AP600 Probabilistic Risk Assessment, Section 17.3, "Release Frequency", Rev. 0, 6/26/92, page 17.1.

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would easily exceed 25 Rem with or without protective action. In fact, Westinghouse estimates an SGTR core melt frequency of 2.6×10^{-9} per reactor-year. 2/

Existing peer-reviewed PRA studies of conventional Westinghouse PWRs suggest that a typical core melt probability for SGTR accidents is typically approximately 2×10^{-6} per reactor-year. 3/ The SGTR initiating event frequency in these PRA studies is approximately 1×10^{-2} to 3×10^{-2} per reactor-year. 4/ In order to demonstrate compliance with both the AP600 design goal and the Westinghouse AP600 PRA result, Westinghouse will have to be able to demonstrate either an improved system response (a combination of hardware and human response) and/or a reduced initiating event frequency for SGTR sequences. Westinghouse implicitly calculates a factor of 1,000 improvement (i.e., the difference between the AP600 result and the NUREG-1150 results) overall for SGTR accidents.

Since most of the details of the Westinghouse accident sequence analysis and quantification for the AP600 PRA are considered to be proprietary **(I will be communicating with you soon concerning the lack of validity of the Westinghouse proprietary claim)**, I will confine me remarks at this juncture to the initiating event frequency, for which details were submitted on a non-proprietary basis. For the AP600, Westinghouse estimates a single-tube SGTR initiating event frequency of 5.3×10^{-3} per reactor-year. 5/ The AP600 value is roughly a factor of two improvement over the NUREG-1150 value.

Westinghouse derived its SGTR initiating event value in Attachment 1 to Appendix A of the AP600 PRA. The factor of two reduction is achieved by a three-step process: (a) assessing the existing historical experience and eliminating a number of the historical tube ruptures from the data base, (b) calculating the frequency of tube rupture based on an individual tube basis, and (c) multiplying this frequency by the total number of SG tubes in the AP600 steam generators.

This process, while not irrational, raises four questions. First, the SGTR initiating event frequencies for previous Westinghouse plant PRAs were calculated based on the number of actual tube ruptures divided by the number of reactor-years of operation. This is a different calculation than performed for the AP600 PRA, and as a result the AP600 SGTR results cannot be directly compared with the SGTR results of PRA studies of existing Westinghouse plants. Second, eliminating historical tube ruptures from the calculation is non-conservative, and this non-conservatism cannot be sustained since there is not yet any AP600-specific operating experience with which to support the arguments which Westinghouse uses to reduce

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2/ Westinghouse, AP600 Probabilistic Risk Assessment, Table 8-1, "Initiating Events Contributing to Core Damage (Base Case - At Power)", Rev. 0, 6/26/92, page 8-7.

3/ For example, the NUREG-1150 estimates were 1.9×10^{-6} per reactor-year for Surry and 2.0×10^{-6} per reactor-year for Sequoyah. *See*, NUREG/CR-4550, Vol. 3, Rev. 1, Part 1, Table 4.10-4; and NUREG/CR-4550, Vol. 5, Rev. 1, Part 1, Table 5-3.

4/ The NUREG-1150 studies for PWRs used an SGTR initiating event frequency of 1×10^{-2} per reactor-year. *See*, for example, NUREG/CR-4550, Vol. 3, Rev. 1, Part 1, page 4.9-4.

5/ Westinghouse, AP600 Probabilistic Risk Assessment, Section B.2.5.3, "Steam Generator Tube Rupture", Rev. 0, 6/26/92, page B-3. It should be noted that the actual calculation, carried out in Attachment 1 to Appendix B of the AP600 PRA, is 5.2×10^{-3} per reactor-year, not 5.3×10^{-3} per reactor-year as cited elsewhere in the AP600 PRA. (*Compare* page B-3 with page B-20 of the AP600 PRA, for example.)

the number of historical tube rupture events. Although Westinghouse in some cases presents plausible arguments for eliminating historical tube ruptures, actually eliminating them from the data base presupposes that operating experience to date with conventional Westinghouse PWRs has identified all of the principal contributors to tube ruptures. No evidence has been presented by Westinghouse to suggest that this is the case, and I am aware of none which supports such a hypothesis. Third, the Westinghouse calculation ignores the 10% tube plugging limit for the AP600 design. This latter point is important since each plugged tube slightly raises the SGTR initiating event frequency since it is calculated on a per-tube basis. Fourth, Westinghouse assesses a factor of 0.8 to account for plant outages. This is excessive for existing Westinghouse plants; since this is effectively a capacity factor correction, a value of 0.65 is more realistic.

To correct for these factors, I have recalculated as follows:

Number of Tube-Years

10,500,000 tube-years times 0.65 capacity factor times 0.9 tube plugging factor; yields 6,142,500 tube-years (compared with Westinghouse value of 7,560,000 tube-years).

Number of Tube Ruptures

Westinghouse counts 3.1 tube ruptures; I count 8 tube ruptures in Westinghouse plants (i.e., none eliminated from historical experience).

Number of Ruptures Per Tube-Year

Westinghouse calculates 4.1×10^{-7} ruptures/tube-year. I calculate 1.3×10^{-6} ruptures/tube-year.

AP600 SGTR Initiating Event Frequency

Westinghouse calculates based on 12,614 tubes, and estimates an SGTR frequency of 5.2×10^{-3} per reactor-year. I calculate based on a 10% tube plugging factor, or a total of 11,353 tubes. Accordingly, I calculated an SGTR initiating event frequency for AP600 of 1.5×10^{-2} per reactor-year, or a factor of almost three greater than the Westinghouse value. 6/ 7/

6/ For comparison purposes, the three Surry steam generators have a total of 10,062 tubes. Assuming a 10% tube plugging allowance, this amounts to 9,056 tubes. The Surry SGTR frequency, using the Westinghouse method, would be 3.7×10^{-3} per reactor-year; using my variation as set forth above, the Surry SGTR frequency would be 1.2×10^{-2} per reactor-year.

7/ I have carried out a separate quantification based on accounting for historical operating experience of all PWRs and PHWRs (CANDU units), and accounting for all twelve historical tube ruptures. Based on this data base, I estimate a tube rupture frequency of 5.4×10^{-3} per reactor-year (12 tube ruptures in more than 2,200 reactor-years of experience through February 1991). This is a broader experience base than Westinghouse has used.

I believe that this calculation is more realistic, and I recommend it to the NRC staff for use in its AP600 PRA review. I would note that this would increase the AP600 SGTR core damage frequency from 2.6×10^{-9} to 7.5×10^{-9} per reactor-year, and overall AP600 core damage frequency from 3.3×10^{-7} to 3.35×10^{-7} per reactor-year. It also increases the SGTR contribution from 0.8% to 2.2%.

Reactor Vessel Rupture Frequency

Regarding reactor vessel rupture, Westinghouse cites the WASH-1400 value of 3×10^{-7} per reactor-year. Westinghouse has apparently forgotten (as it is common to do) that the WASH-1400 value is a median, not a mean. The mean value, as Brookhaven National Laboratory pointed out in its review of the Oconee PRA, is 1.1×10^{-6} per reactor-year. Even taking Westinghouse's factor of ten reduction at face value (it cannot be said that Westinghouse went to very great efforts to justify this factor of ten), this results in a reactor vessel rupture contribution to AP600 core damage frequency of 1.1×10^{-7} per reactor-year. This increases the AP600 core damage frequency from 3.3×10^{-7} to 4.1×10^{-7} per reactor-year, and increases the contribution of vessel rupture from 9.1% to 26.8%. (It should be noted that this assumes, as does Westinghouse, that vessel rupture automatically leads to core melt. This may be conservative for the AP600 configuration -- the in-containment RWST could flood the reactor cavity and cover the core. In view of the contribution of vessel rupture to core damage frequency for AP600, this may be worth investigating.)

These two changes increase the AP600 core damage frequency from 3.3×10^{-7} to 4.2×10^{-7} per reactor-year. The changes also increase the 25-Rem site boundary dose frequency slightly from 3×10^{-8} to 3.5×10^{-8} per reactor-year (assuming that SGTR sequences contribute on a 1 for 1 basis and that vessel rupture does not contribute).

Seismic Risk

I note that Westinghouse has elected to perform a seismic margin evaluation in lieu of a seismic PRA for AP600. While such an approach is permitted in response to NRC Generic Letter 88-20 (the IPE Generic Letter) for an operating plant, it is not permitted under NRC regulations which require a PRA for standard plant designs for which certification is sought under Part 52; *see* 10 CFR 52.47(a)(5). 8/ Westinghouse is required to perform a full seismic PRA for AP600. Given the existing AP600 internal events PRA and the AP600 seismic margin analysis, extending these analyses to a seismic PRA should not be time-consuming, difficult, or very expensive. The NRC staff should communicate this requirement to Westinghouse promptly.

Conclusion

Now that at least some of the details of the AP600 PRA have become available, it is clear that there are problems with portions of the analysis which suggest that the results are optimistic. I do expect, however, that unless a serious design error has been made regarding seismic or fire events, the AP600 design should demonstrate an improvement on core damage frequency from existing PWR designs.

8/ I note that the NRC staff required General Electric to include a seismic PRA for the GESSAR-II FDA.

In order to promote additional public interaction on the AP600 application, I believe that the NRC staff should undertake an early review of the AP600 PRA with an eye toward publicly releasing as much of the document (and the related fault and event trees) as is possible while still protecting Westinghouse's legitimate proprietary interests. The sooner the public is able to review and understand the risks posed by operation of plants employing the AP600 standard design, the sooner the safety issues involved in the design can be identified, publicly aired, and resolved. This will permit timely issuance (if justified) of a Final Design Approval for AP600 and publication of a proposed Design Certification rule. If, however, the NRC staff waits until later in the process before carrying out its review of the validity of proprietary claims, it is predictable that delays will occur. Such delays are entirely avoidable at this stage of the review; the same will not be true at a later date.

I would be pleased to discuss these matters with the NRC staff if there are any questions. I wish the staff the best of luck on its AP600 PRA and SSAR reviews, and expect to communicate further with the staff as the reviews progress.

Sincerely,

Steven C. Sholly
Senior Consultant

cc: Mr. Thomas Kenyon, NRR/PDST