WESTINGHOUSE AP1000

DESIGN CERTIFICATION REVIEW

SPECIFIC UNRESOLVED ISSUES FROM

NRC STAFF'S REQUEST FOR ADDITIONAL INFORMATION

CONCERNING

PROBABILISTIC RISK ASSESSMENT

TO BE DISCUSSED AT

FEBRUARY 26, 2003

PUBLIC MEETING

RAI 720.038

As discussed in RAI number 720.038, an important objective in the AP1000 design certification is to identify important PRA insights and assumptions to ensure that they have been addressed in ITAAC and D-RAP and COL action items. The following questions concern the lack of documentation regarding shutdown risk significant assumptions and features of the AP1000 design. Given the updated common cause analyses for the HP and LP squib valves and the shorter operator response times, the staff needs importance and sensitivity analyses for the AP1000 shutdown PRA documented in the AP1000 shutdown PRA rather than referring the reader to the AP600 Shutdown PRA. The sensitivity analyses should include:

a. The AP1000 Shutdown CDF based on a licensee following the minimum compliance with Technical Specifications which includes the licensee having only one IRWST injection and recirculation path operable during modes 5 and 6.
b. The results of the focused AP1000 shutdown PRA.
c. The AP1000 Shutdown CDF assuming all human error probabilities (HEPs) are set to .5 which includes HEPs RCS-MANODS1 and RCSMANODS2.

2 Please justify in the AP1000 DCD section 19.E.4.8.1 why the NOTRUMP analyses performed for the AP600 plant to show the plant response to a loss of RNS cooling in Mode 4 with the RCS intact and in Mode 5 with the RCS is acceptable for the AP1000 design.

3. Vacuum refill of the RCS from drained conditions was mentioned; however, no risk assessment was done for this plant configuration. Passive RHR should be operable according to the AP1000 Technical Specifications during this plant configuration since the RCS would be closed which should reduce risk. However, Westinghouse should document in the AP1000 Shutdown PRA the additional plant risk occurring from vacuum refill of the RCS during drained conditions and how this risk affects the AP1000 shutdown PRA results.

4. Based on the RAI response to 720.065, the staff does not believe that the ability to close the containment in the AP1000 is the same for AP600 because the time to boiling is reduced from 17 to 10 minutes. The staff also noted that shutdown LRF frequencies were reported in AP1000 Implementation of the Regulatory Treatment of Nonsafety-Related Systems Process (on Table 2-2). However, there is no discussion of shutdown LRF in the AP1000 shutdown PRA, nor is there a discussion regarding the failure likelihood of closing containment given a severe accident at shutdown. The staff is requesting Westinghouse to document in the AP1000 shutdown PRA : (1) the assessment used to estimate that likelihood that the operators could fail to close containment during shutdown, and (2) a corresponding discussion of the shutdown LRF frequencies in the AP1000 shutdown PRA.

5. Westinghouse's response to RAI 720.070 is not adequate for the staff to derive AP1000 risk insights regarding shutdown fires, shutdown floods and seismic events at shutdown.

a. As reported in RAI 720.070, the AP600 shutdown fire frequency is comparable to the AP600 at power fire frequency. Thus, Westinghouse is requested to document changes in the AP1000 shutdown fire assessment from the AP600 shutdown fire assessment. Specifically, Westinghouse needs to identify and document in the AP1000 Shutdown PRA: (1) any differences in equipment locations in the various fire areas and zones with respect to the AP600 design and (2) the qualitative or quantitative impacts (if necessary) of such differences on shutdown risk results and shutdown risk insights.

b. The staff did not find any AP1000 PRA based insights regarding how transient combustibles will be controlled at shutdown to maintain the assumed shutdown ignition frequencies. Westinghouse needs to document in the AP1000 shutdown PRA how transient combustibles at shutdown will be controlled.

c. Considering the updated common cause analysis for the HP and LP squib valves and the revised shutdown initiating event frequencies based on an 18 month refueling cycle, Westinghouse is requested to provide the dominant AP1000 shutdown fire scenarios in the AP1000 shutdown PRA.

d. Westinghouse is requested to document in the AP1000 Shutdown PRA any changes from the AP600 shutdown internal floods assessment that could impact AP1000 shutdown risk insights.

e. Westinghouse is also requested to document in the AP1000 Shutdown PRA the dominant AP1000 shutdown flooding scenarios.

DISCUSSION TOPICS RELATED TO RESPONSES TO RAI's TO BE DISCUSSED AT THE 2/26/2003 MEETING BETWEEN NRC AND WESTINGHOUSE

RAI 720.027

The staff had requested additional information about several differences in initiating event category frequencies used in the AP600 and the AP1000 probabilistic risk assessments (PRAs). These differences are related to (a) various loss of coolant accident (LOCA) categories, (b) steam generator tube rupture (SGTR) accidents, and (c) passive residual heat removal (PRHR) tube rupture accidents. Westinghouse's response need further clarification in the following areas:

1. For LOCA categories, Westinghouse states that in the AP1000 PRA "operating experience" data reported in NUREG/CR-5750 for pipe breaks as opposed to data from a pipe break analysis used in the AP600 PRA were used. However, the NUREG/CR-5750 data rely on expert opinion and include significant uncertainty. In addition, since NUREG/CR-5750 was published additional information (e.g., Davis Besse finding) is available. The impact of this uncertainty on results and conclusions, especially in combination with other outstanding issues (e.g., late containment failure modeling and common cause failure probabilities of squib valves), needs to be investigated. In particular, the combined effect of such uncertainties on the process used to identify "low margin risk significant" sequences for bounding thermal-hydraulic (T-H) uncertainty and on the regulatory treatment of non-safety systems (RTNSS) process should be investigated. Westinghouse's response to this RAI refers to other RAI responses which do not really include a response to the staff's question (e.g., about the combined impact of this uncertainties on the RTNSS process).

2. It is stated that the frequency of SGTR events assumed in the AP1000 PRA is based on a more recent calculation that was performed in conjunction with a replacement steam generator project which is proprietary to Westinghouse. The staff would be interested in reviewing this information.

RAI 720.028

The staff requested additional information about the impact of two potentially significant differences between the AP600 and the AP1000 PRAs in the categorization of LOCA initiating events on the approach used to identify "low margin risk significant sequences" and address T-H uncertainty. One difference involves combining two AP600 PRA LOCA categories (i.e, the medium LOCA and the intermedium LOCA) into one AP1000 PRA category (labeled medium LOCA). The other difference involves the splitting of the AP600 PRA large LOCA category into two categories, the large LOCA category (pipe breaks) and the spurious opening of the automatic depressurization system (ADS) valves category (SPADS).

Westinghouse's response covers the major part of the question. However, the staff would like to get further clarification on the following points:

1. The SPADS category includes a sequence with one accumulator available and only three ADS valves opening (sequence 8 in expanded event tree) which is assumed to be a success (i.e., no core damage). This frequency of this sequence was estimated to be 1.07E-9 (could be significantly higher if uncertainty associated with the CCF probability of squib valves is considered) which does not appear to be bounded. Please clarify.

2. In the RAI response it is stated: "NLOCA required one ADS stage 2/3 valve to open to allow RNS injection and MLOCA did not require any of these valves. In the AP1000, the more restrictive NLOCA success criteria was applied to all breaks in the MLOCA range..." However, in the expanded MLOCA event tree for AP1000 sequences with no ADS 2/3 success are shown as Ok (e.g., sequences 2 and 4).

RAI 720.029

The staff requested clarification about the basis for time windows available for several operator actions associated with specific LOCA sequences. Westinghouse's response needs further clarification regarding the following items:

1. Table provided in the response does not appear to provide adequate information for the reader to understand what human actions are involved and what assumptions are made in calculating the human error probabilities involved. First column, labeled "Event" reports the initiating event category, the second column, labeled "Time Window" does not discuss time windows.

2. Discuss whether the T-H analyses used as the basis for calculating the time windows used in the HRA include T-H uncertainties.

3. The time window for event RHN-MAN01 was revised in Table 6-3 to 10 minutes. However, it appears that the HEP calculated in Chapter 30 of the PRA is based on a time window of 20 minutes.

4. It is stated in Table 6-3 that the time window for human action CMN-MAN01 is consistent with associated recognition action but it is not stated what the time window is. Also, in Chapter 30 where the HEP is calculated, event CIT-MAN0S is listed instead of event CMN-MAN01.

5. In the revised Section 6.3.2.5 under "Medium LOCA," successful PRHR is required for successful operator action. However, PRHR does not appear at all in the MLOCA and CMT line break event trees or in the tables where the steps for calculating HEP are reported.

RAI 720.030

The AP1000 PRA event trees include a top event for containment cooling (event CHR). It is stated that *"For success paths that result in steam release to the containment, the success of containment cooling (PCS or RNS) is modeled. If containment cooling is successful, then the*

path ends in an OK state. If PCS water cooling is not successful, then the path goes to a special OK end state to allow containment integrity sensitivity studies to be made." This "special OK" end state is labeled "late containment failure (LCF)" end state on page 4-141 and defined as an end state *"...where the containment heat removal by either passive containment cooling system (PCS) or component cooling water (CCS) heat exchangers via normal residual heat removal (RHR) fails."*

The staff requested clarification about the meaning of the "special Ok" status. Westinghouse responded that a sensitivity study shows that even if the LCF state is considered to be a core damage, the plant CDF would increase by only 29%. The staff needs further clarification about the following:

1. The major contributors to the 29% CDF increase and how this impacts the LRF.

2. The impact of this assumption on the focused PRA where no credit is taken for the non-safety related systems and the RTNSS process.

RAI 720.033

The staff requested clarification on several statements and common cause failure (CCF) probabilities related to explosive (squib) and check valves, included in Chapter 12 on Passive Core Cooling/In-Containment Refueling Water Storage Tank and in Chapter 29 on Common Cause Failure Analysis. Westinghouse's response states that the same group of valves are available following a safety injection (SI) line break as when there is no SI line break. The staff does not agree with this assumption because when an injection line fails the valves in that line are obsolete. In addition, the calculation of the common cause failure probabilities for two and three-out-of-six valves needs clarification (e.g., number of valves in injection vs. recirculation lines required to mitigate an SI break accident).

RAI 720.035

The staff requested Westinghouse to explain the process that will be used to verify that a PMS designed with the "Common Q" option will have equivalent or better reliability than the system modeled in the PRA and how the introduction of the "Common Q" option will affect important PRA-based insights about the PMS. Westinghouse responded that "the PRA results are not sensitive to small changes in PMS failure probabilities" and "The general architecture of the Common Q PMS is similar to that modeled in the AP1000 PRA and includes the features listed above." The staff needs further clarification, including a direct comparison of the design features found to be important in the PRA between the "Common Q" option and the PMS modeled in the PRA. In addition, a direct comparison of the "design certification requirements" for the two cases can help clarify the issue. Based on the results of these comparisons, the identification of new "design certification requirements" to ensure PMS reliability may be required. The same comments apply also for DAS and PLS designed with the "commercial off-the-shelf hardware and software current at the time of construction" option.

RAI 720.037

The staff requested the use a systematic approach to identify "risk significant low margin" sequences for detailed T-H uncertainty assessment. Westinghouse provided such an approach. However, there are some points that need further clarification. Examples are:

1. Impact of open issues on the frequency of analyzed sequences.

2. Scope of expanded event trees. It appears that there are some gaps in the rational used to limit the event trees that were expanded. The staff needs more details about the reasons for limiting the number of the event trees that were expanded and analyzed.

3. Discussion of investigation performed to ensure that there are no adverse system interactions between passive and active systems.

4. Explanation of LLOCA sequences 7 to 10. On what basis are these sequences found to be successful even when T-H uncertainties are included? Why sequence 6 (2 CMTs and one Acc available) leads to core damage but sequences 7 to 10 (1 CMT and two accumulators available) are ok?

5. Sequence 21 of LLOCA classified as UC8 but was not analyzed because the calculated frequency is less than 1E-9/year. However, if a more conservative frequency for large breaks and a more conservative probability for the failure to isolate the containment are considered, the frequency of this sequence will be higher than the cutoff frequency.

6. Discussion of impact of timing of operator actions on T-H analysis (e.g., for sequences requiring manual ADS actuation).

7. Discuss the basis for assuming that the SI-LB sequences 18 to 21, involving failure to isolate the containment and availability of only one CMT and one Acc, are Ok. Similarly for sequence 23 (one CMT and no Acc. available) and sequence 28 (no CMT and only one Acc. available).

8. If credit is taken in the T-H analysis for the PRHR, this system needs to be included in the appropriate event trees.

9. Discussion of the impact of T-H uncertainty on passive containment cooling success criteria assumed in the PRA.

RAI 720.038

Westinghouse identified important PRA insights and assumptions and provided a list of design certification requirements, such as requirements for inspection, tests, analyses and acceptance criteria (ITAAC), the requirement for a design reliability assurance program (D-RAP) and combined operating license (COL) action items. However, the staff cannot close this issue until all other outstanding issues are closed and significant progress in preparing the final safety evaluation report (FSER) and the design control document (DCD) is being made.

RAI 720.039

The staff requested Westinghouse to provide all important steps in the process of using PRA results to identify systems, structures and components (SSCs) for regulatory oversight as well as the type and level of such oversight for non-safety-related systems. This information should account for uncertainties in the AP1000 PRA so that it can be used by the staff to make similar conclusions, about the need for non-safety-system oversight, to those made for the AP600 design (e.g., as documented in the AP600 FSER Chapter 19.1.7 "PRA input to the RTNSS Process.)" Westinghouse did not provide this information with its response.

Review of W Responses to RAIs Related to Level 2 and 3 PRA and Severe Accidents (RAIs 720.041 - 720.063)

RAIs 720.041 through 720.063 address concerns regarding the Level 2 and 3 PRA, portions of the deterministic analyses of severe accidents, and the evaluation of severe accident mitigation design alternatives (SAMDAs) for AP1000. Additional aspects of the deterministic analyses of severe accidents (e.g., fuel coolant interactions) are addressed in other 720-series RAIs and are not addressed below.

The additional information provided by W is generally responsive to the concerns raised in the RAIs. However, for many of the RAIs, portions of the requested information was not provided. Those RAIs which have not been fully addressed are:

RAIs 720.042, 043, 046, 048, 050, 053, 055, 056, 058, and 060. Those aspects of the RAI requiring additional information from W are summarized below.

720.042 The RAI requested AP1000-specific analyses and stated that the information provided "should include a comparison of event timing, fraction of core melted, hydrogen generation rates and quantities, mass and superheat characteristics of debris relocating into the lower plenum, and fission product release histories for representative sequences in each accident class." This has not been provided.

720.043 The RAI noted that time windows available for operator actions in AP1000 are shorter than for AP600 and requested that W provide an assessment of the shorter times on human error probabilities and containment performance. The response addressed these impacts for 1 operator action, but 3 additional actions have shorter times in AP1000 and were not addressed.

720.046 The RAI questioned the completeness of the containment isolation fault tree success criteria tables in Chapter 24. The response explained why some of the valves are not included, but certain disparities still exist. Specifically, the following valves appear to be modelled for "CI" but are not listed in Table 24-8: V058B, V074A, V075A, AOV250A. Startup feedwater penetration check valves 256A and B are mentioned in the response, but are not shown in any of the containment isolation valve tables.

720.048 The RAI requested that W provide AP1000-specific assessments for each of the alternate debris configurations identified in INEEL's review of external reactor vessel cooling for AP600. W did not provide these assessments in their response, but appears to have performed such analyses based on information they presented during a 1/24/2003 meeting with ACRS.

720.050 The RAI requested that W either: (1) establish the applicability of the ULPU Configuration III test results to AP1000, or (2) develop AP1000-specific test data based on the prototypical insulation and flow conditions for AP1000. This was not addressed in the response.

720.053 The RAI noted that events with core damage could result in higher containment pressures than the sequence on which the probability value for node "IF" is

based. The response provided qualitative arguments regarding sequence selection. Request that W provide pressure histories for core melt sequences representative of those evaluated at node "IF" to confirm.

720.055 The RAI requested a deterministic assessment of DCH pressure loads based on the methodology developed as part of DCH issue resolution. The response repeated the same qualitative arguments contained in PRA, Appendix B.

720.056 The RAI noted a number of inconsistencies between the offsite consequence estimates for AP1000 and AP600. AP1000-specific results have now been provided and the noted inconsistencies have been eliminated. However, two new inconsistencies are noted -- the dose for release category "CI" is identical to the AP600 value, and the dose for release category "CFE" is less than the AP600 value. The reasons need to be explained.

720.058 The RAI requested that W provide an assessment of the impact on basemat melt-through times and containment pressure (for both limestone and basaltic concretes) assuming that oxide/metallic separation does not occur, in order to confirm their conclusion regarding basemat failure and the adequacy of the sump curb design. In their response, W indicated that the sump curb height will be increased, but they did not provide the requested assessment.

720.060 The evaluation of SAMDAs was omitted from the PRA/DCD and submitted in response to this RAI. The evaluation does not address a number of items called out in the RAI and has several additional deficiencies, as summarized below:

- the cost benefit methodology appears to be based on an outdated guidance document (NUREG/CR-3568, 1983). The current guidance for regulatory analysis contained in NUREG/BR-0184 (1997) and NUREG/BR-0058 (2000) should be applied.
- replacement power costs were omitted. These averted onsite costs need to be included consistent with SECY-99-169.
- the CDF and population dose values used in the evaluation only reflect internal events. The contribution to CDF and population dose from shutdown and fire events should also be included.
- the RAI requested an explanation of how insights from the AP1000-specific PRA and supporting risk analyses for external and shutdown events, including importance analyses and cutset screening, were used to identify potential plant improvements. This was not addressed in the response.
- the RAI requested justification that the potential improvements identified through a systematic process (as suggested above) are included within the set of 15 SAMDAs identified in Appendix 1B of the AP1000 DCD. This was not addressed in the response.

RAIs 720.82, 85, 88/89, 92, 95, 96 - need clarification (see below follow-up questions)

RAI 720.082:

1. Please clarify the following aspects of sequence #20 (1ATRA-17) of the AP1000 PRA. If the cutsets comprising this sequence include substantial relative contributions with different characteristics regarding these points, also specify approximate frequency contributions.

a. Although IVR by means of lower head cooling cannot be credited for this high-pressure sequence, what is the status of cavity flooding from the IRWST?

b. Are the gutter drain valves assumed to close successfully? (i.e., is condensate from the containment directed to the containment sump or to the IRWST in this scenario?)

RAI 720.085:

The AP600 in-vessel steam explosion analysis that was cited in support of the AP1000 neglects the possibility of initially small FCIs (with little energetic potential) being a driver for larger melt crucible failures that would increase the melt pour rate. Please elaborate on how these events were considered or bounded for RPV survival in-vessel?

RAI 720.088-089:

1. A detailed description of the finite-difference model that has been used to perform calculations to support the side failure and melt relocation arguments. This should include the description of the model assumptions, pedigree, and their experimental basis.

2. A demonstration of its technical position by considering a wider range of phenomenological uncertainties including the effects of other debris relocation alternatives, the metallic layer depths, and the melt pool stratification and layering, on the AP1000 lower head integrity. In any reanalysis, please consider the uncertainties associated with the measured critical heat flux on the outside surface of the AP1000 lower head.

RAI 720.092:

The Westinghouse design criteria do not address how many igniters should be placed within each AP1000 compartment. The issue of igniter spacing has not been addressed for the AP600 or AP1000 plants. Please provide the technical basis for the numbers and the placement of igniters in AP1000 containment.

RAI 720.095:

1.What are the mixture compositions within the AP1000 containment for a representative accident with 100% active cladding reaction throughout the entire sequence, including times beyond the intermediate time frame?

2.What is the probability of DDT for mixture compositions beyond the intermediate time frame and when the entire containment is treated as an individual room for the purposes of the global burn?

RAI 720.096

Please provide a detailed sample calculation for the problem of solving the AICC pressure (equations shown in Section 41.9.2 (Revision 0)). It is presumed that this is the procedure used to produce the values in Table 41-4 and the basis for the values reported in Section 41.11. For example, using Equation 41-2 and the values given below the equation, it is not possible to obtain the same values for gas masses shown in Table 41-4. Furthermore, Equation 41-6 lists four gas constituents yet Table 41-4 lists five. If one uses the values provided in Section 41.9.2, one would get estimates of the AICC pressure that exceed the ASME service level C stress intensity limit of 91 psig.