UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

September 19, 2011

The Honorable Gregory B. Jaczko
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: REVISION 19 TO THE AP1000 DESIGN CONTROL DOCUMENT AND THE AP1000 FINAL SAFETY EVALUATION REPORT

Dear Chairman Jaczko:

During the 586$^{th}$ meeting of the Advisory Committee on Reactor Safeguards (ACRS), September 8-10, 2011, we reviewed those portions of the NRC staff's Final Safety Evaluation Report (FSER) for the AP1000 Design Control Document (DCD) amendment which were affected by Revision 19 to the DCD. The Westinghouse Electric Company (WEC) submitted Revision 19 on June 13, 2011, and the NRC staff's FSER is dated August 5, 2011. Our Subcommittee on AP1000 also reviewed changes contained in Revision 19 during a meeting on August 16, 2011. During these meetings, we had the benefit of discussions with representatives of the NRC staff, WEC, and members of the public. We also had the benefit of the documents referenced.

We have previously reviewed other changes contained in the DCD amendment, as documented in our letters dated December 13, 2010; December 20, 2010; and January 19, 2011.

## CONCLUSION

The changes proposed in the AP1000 DCD amendment, including those made in Revision 19, maintain the robustness of the previous certified design. We conclude that there is reasonable assurance that the revised design can be built and operated without undue risk to the health and safety of the public.

## BACKGROUND

Most of the changes to the DCD contained in Revision 19 involve editorial corrections and inclusion of conforming items previously identified in the Advanced FSER which was the basis for our prior letters. A few of the Revision 19 changes include new information, and several of these changes are discussed further below.

**DISCUSSION**

Enhanced Shield Building (ESB)

There have been no changes to the ESB design since the review documented in our letters of December 13, 2010, and January 19, 2011. However, WEC has performed additional analyses and included Tier 2* information, as requested by NRC staff.

Passive Cooling System (PCS) Tank

The ESB rooftop PCS tank wall is identified in the DCD as a critical structural section. The overall behavior of the building is obtained by a response spectrum analysis of a global finite-element model, which is referred to as the NI05 model. Results for the tank wall from this model were reported in Revision 18 to the DCD.

Revision 19 included new results based on an equivalent static analysis of a more detailed finite-element model of the tank and ESB roof. The analysis applied the maximum acceleration from time-history calculations with the hydrodynamic loads due to sloshing of water in the tank applied as a pressure on the tank wall. Because of the symmetry of the tank and roof, a quarter of the structure was modeled.

This new, more detailed, analysis confirmed that the design of the PCS tank is acceptable, and no changes to the design were required. We agree with the NRC staff that the more detailed analysis of this area of the ESB was appropriate and should be included in the DCD.

ESB Seismic and Thermal Load Combination

Prior to Revision 19, the ESB was analyzed for a number of loads including those due to a safe shutdown earthquake (SSE) and those due to extreme ambient temperatures. At the request of the NRC staff, these loads were combined and the analysis results were included in Revision 19.

The worst-case ambient conditions are represented by a winter condition with an external temperature of -40$^{o}$F and an internal temperature of 70$^{o}$F, and a summer condition with an external temperature of 115$^{o}$F and an internal temperature of 70$^{o}$F. The analysis shows that the winter condition is the most limiting due to the larger temperature difference. For this case, the out-of-plane shear capacity of the structure exceeds the out-of-plane shear demand in the regions of the structure with steel composite modules.

The governing demand-to-capacity ratio in the critical region for thermal loading is steel plate yielding, which is a ductile limit state. We agree with the staff's conclusion that the WEC's analysis of the thermal and seismic load combination for the shield building satisfies ACI 349 code provisions and is acceptable.

Radiative Effects on Thermal Loads

A concern was raised by a member of the public (Ref. 6) that the estimation of thermal loads on the ESB did not include the effects of radiative heating or cooling. WEC performed additional calculations to quantify the impacts of these effects.

An American Society of Heating, Refrigerating and Air-Conditioning Engineers publication includes tables of effective temperatures that provide the same rate of heat transfer into the surface as would the combination of solar gain, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with the outdoor air. These tables were used to estimate the temperature history of the ESB wall.

WEC calculated that the resulting maximum ESB surface temperature, including solar gain, is approximately 129$^{o}$F. Their stress analysis using this surface temperature showed that the solar gain has no significant effect on the load combination of ambient thermal plus SSE, and there is no significant reduction in the overall design margin. This result is consistent with our expectation that any change would be relatively small, as compared to that due to the winter ambient temperature difference of 110$^{o}$F. We therefore conclude that this issue can be considered resolved.

Inclusion of ESB Design Details in the DCD

Revision 19 includes additional Tier 2* material describing the steel modules that comprise the bulk of the ESB wall and the connection of the modules to both the basemat and the conventional reinforced concrete roof of the auxiliary building.

As we noted in our December 13, 2010, letter, there are no consensus standards governing the steel module construction used in the ESB, although the DCD does commit to use of AISC-N690, ACI-349, and AWS structural and reinforcing steel welding codes as applicable to the modules and their connections. The added Tier 2* information provides regulatory control over additional details of the module design to address the lack of specific code requirements for some features.

As examples, the added information includes a performance requirement of the tie bar to steel face plate welds, which have no counterpart in AISC-N690, and a weld geometry requirement on the plate-to-plate welds for modules. This information, together with the other Tier 2* information, including 14 critical structural sections, provide appropriate regulatory control over the design of the ESB.

The staff and WEC have expended substantial efforts in deciding which details need to be included in the DCD, in lieu of reference to codes and standards which presently do not address such details for the design used. We again note, as we did in our December 13, 2010, letter, that it would be preferable to have codes and standards for such structures that have broad consensus concerning such details.

Containment Accident Pressure Analysis

The calculation of containment accident pressure was updated in Revision 19, increasing the peak pressure to 58.3 psig as compared to 57.8 psig previously. The most significant contributions to the increase resulted from the increase in time assumed to reach steady-state PCS water coverage and from updates of the estimates of the mass and energy release into containment during a loss of coolant accident. The first of these contributions arose from the resolution of an earlier ACRS comment.

Changes were also made in the evaluation model which tended to decrease the peak pressure, the most important of these being the inclusion of certain heat sinks such as floor gratings.

These changes to the containment evaluation model inputs took into account the updated plant design information. The analysis, primarily done using WGOTHIC, including the consideration of heat sinks, was performed using a previously accepted methodology which results in conservatively high containment pressures. Independent calculations performed by NRC staff using MELCOR also confirmed that the WGOTHIC-based results were conservative. The heat sinks added in the Revision 19 calculation update were incorporated as Tier 2* information.

While the containment peak pressure of 58.3 psig is close to the containment design pressure of 59 psig, we find the re-evaluated containment pressure documented in Revision 19 to be based on a sufficiently conservative methodology and to be acceptable.

Radiative Effects on Containment Evaluation Model Validation

An additional concern was raised by the member of the public (Ref. 6) regarding the effect of radiative heating due to insolation and radiative cooling on the quality of the data obtained from the Large Scale Tests (LSTs) which were performed outdoors.

The LSTs provided data on condensation in the presence of non-condensable gases inside large containment-like vessels cooled by an evaporating water film flowing down the outside surface. The test vessel itself was surrounded by an acrylic enclosure that formed an annulus through which air was drawn to simulate the natural convection of air between the containment and ESB. While the LSTs were reduced in scale compared to the plant, they were still large enough to assess the validity of the evaluation model correlations, which were developed from much smaller scale tests.

The concern was that solar radiation incident on the evaporating water film, which cools the outside of the LST vessel, would cause a higher evaporation rate than would otherwise result, thus leading to non-conservatively high heat transfer coefficients.

The LST heat fluxes used to estimate the heat transfer coefficients both on the inside and outside of the pressure vessel, and on the outside of the pressure vessel due to the water film, were evaluated in three different ways. The first involved measuring the amount of steam condensed within the pressure vessel, the second involved measuring the heat transfer through the wall using embedded thermocouples, and the third involved performing a heat balance on the water and air cooling the outside of the pressure vessel. If insolation had an effect, the heat balance on the water and air would yield a markedly higher value than the other measures of heat flux.

Examination of the data indicates that the heat fluxes measured by these three independent methods were the same, within the scatter of the data, over the whole range of conditions. Following our assessment and an independent assessment provided by WEC, we conclude that radiative heating or cooling had no effect on the LSTs and the data from the tests are suitable for validating the evaluation model.

We also considered whether insolation on the ESB exterior would affect the removal of accident heat load by the PCS. WEC provided analyses that showed this effect was negligible for two reasons. First, because the ESB has a large thermal mass, the temperature changes on its inside wall resulting from insolation are very small. Second, because the heat removal from the containment is due primarily to evaporative cooling, even significant increases in the air temperature at the ESB inlet to the annulus would have a small effect on the peak containment pressure. Prior parametric analyses by WEC showed that an increase of 10$^{o}$F in inlet air temperature results in an increase in peak containment pressure of only ~0.05 psi. We therefore conclude that solar heating will not result in an unacceptable increase in peak containment pressure.

<u>Reactor Coolant Pump (RCP) Flywheel Retaining Ring Material Testing</u>

In our letter dated December 13, 2010, we recommended that the material selected for an RCP flywheel retaining ring designed for long term service without periodic inservice inspection should be qualified by testing in a reactor coolant environment. WEC responded to this concern by implementing a testing program. We commented on this program in a letter to the EDO dated May 19, 2011, and WEC responded with an updated plan during the August 16, 2011, subcommittee meeting. We concur with the updated WEC test program as described to us.

In summary, we agree with the staff's FSER, including Revision 19 to the DCD. The changes incorporated by Revision 19 maintain the robustness of the previously certified design. We conclude that there is reasonable assurance that the revised design can be built and operated without undue risk to the health and safety of the public.

Sincerely,

***/RA/***

Said Abdel-Khalik
Chairman

**REFERENCES**


1. AP1000 DCD Revision 19 Sensitive Version, June 13, 2011 (ML11171A287)

2. The Final Safety Evaluation Report for the AP1000 DCD Revision 19, FSER for the DCD, August 2011 (ML112061231)

3. Design Report for the AP1000 Enhanced Shield Building, APP-1200-S3R-003, Revision 4, June 15, 2011 (ML111950098)

4. AP1000 Shield Building Design Details for Select Wall and RC/SC Connections, APP-GW-GLR-602, June 14, 2011 (ML111680018)

5. Evaluation of the Effect of the AP1000 Enhanced Shield Building Design on the Containment Response and Safety Analyses, APP-GW-GLR-096, Revision 3, June 14, 2011 (ML111680190)

6. Statement and materials presented to the 586th Full Committee Meeting by Dr. Susan Sterrett (ML11256A256, ML11256A258, ML11256A266)

7. ACRS Letter, Report on the Final Safety Evaluation Report Associated with the Amendment to the AP1000 Design Control Document, December 13, 2010 (ML103410351)

8. ACRS Letter, Long-Term Core Cooling for the Westinghouse AP1000 Pressurized Water reactor, December 20, 2010 (ML103410348)

9. Letter, Report on the Safety Aspects of the Aircraft Impact Assessment for the Westinghouse Electric Company AP1000 Design Certification Amendment Application, January 19, 2011 (ML110170004)

10. ACRS Letter, Response to the February 5, 2011, EDO Letter Regarding the Final Safety Evaluation Report Associated with the Amendment to the AP1000 Design Control Document, May 19, 2011 (ML11136A214)

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1. AP1000 DCD Revision 19 Sensitive Version, June 13, 2011 (ML11171A287)

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