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Subject: Methodologies used for the AP1000 Evaluation of Long-term Core Cooling

The purpose of this letter is to address the use and application of methodologies described in WCAP-16406-P-A, "*Evaluation of Downstream Sump Debris Effects in Support of GSI-191*", March 2008, and WCAP-16793-NP, "*Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid*", May 2007 as referenced in APP-GW-GLR-079 Revision 3, Technical Report 26, "*AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA,*" (TR-26) on March 28, 2008.

Title 10 of the Code of Federal Regulations Part 52.47, *Contents of Applications; Technical Information*, requires the application must contain a final safety analysis report (FSAR) that must include the proposed technical resolutions of those Unresolved Safety Issues and medium- and high-priority generic safety issues which are identified in the version of NUREG–0933 current on the date up to 6 months before the docket date of the application and which are technically relevant to the design. These issues are discussed in Section 1.9.4 of the AP1000 Design Control Document (DCD). The Section 1.9.4 proposed technical resolution of Generic Safety Issue (GSI) 191, Assessment of Debris Accumulation on PWR Sump Performance, in Revision 16 of the DCD states: Technical report APP-GW-GLR-079, *AP1000 Verification of Water Sources for Long-Term Recirculation Cooling Following a LOCA*, evaluates the potential for debris to plug the AP1000 screens consistent with Regulatory Guide 1.82 Revision 3 and subsequently issued Nuclear Regulatory Commission guidance.

With respect to the downstream effects evaluation in APP-GW-GLR-079 Westinghouse referenced and used relevant portions of the methodologies described in WCAP-16406-P-A and WCAP-16793-NP. The data and methods used to evaluate ex-vessel downstream effects are outlined in WCAP-16406-P-A. For downstream effects associated with the core, the potential for deposition of post-LOCA chemical products on the fuel cladding and the consequential effects on clad temperatures was addressed using the methods developed and documented in WCAP-16793-NP. Westinghouse has evaluated the applicability of these methodologies to the AP1000 and concluded that they are applicable and should be accepted for use on the AP1000. A basis for this conclusion is provided below.

The NRC reviewed and accepted WCAP-16406-P-A in its Final Safety Evaluation for Pressurized Water Reactors Owners Group (PWROG) Topical Report (TR) WCAP-16406-P, "*Evaluation of Downstream Sump Debris Effects in Support of GSI-191,*" Revision 1 (TAC NO. MD2189), dated December 20, 2007. With respect to reactor internal and fuel blockage evaluations, The Final Safety Evaluation states that

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Licensees should refer to WCAP-16793-NP and the NRC staffs Safety Evaluation of WCAP-16793-NP, in performing their reactor internal and fuel blockage evaluations.

WCAP-16793-NP is currently under NRC review. On March 7, 2008 the NRC issued their draft safety evaluation for Pressurized Water Reactor (PWR) Owners Group (PWROG) Topical Report (TR) WCAP-16793-NP, Revision 0, "*Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid.*" The Final Safety Evaluation Report for WCAP-16793-NP has not been issued, due in part to questions raised by the Advisory Committee on Reactor Safeguards (ACRS) on portions of the methodology presented in WCAP 16793-NP during an March 19, 2008 ACRS meeting. The portions of the methodology questioned by the ACRS centered around core blockage and the ability to ensure long term core cooling when considering the consequences of combined fibrous and particulate debris loads entering the reactor coolant system and collecting on fuel elements (debris capturing devices and support grids) following a high energy line break.

The questions identified by the ACRS are not applicable to the AP1000 Standard Design. For the AP1000, the generation of fibrous debris due to postulated high energy line breaks is precluded through the design of the plant. Specifically, the AP1000 Standard Design does not use fiberglass insulation in areas of the plant that may be impacted by high energy line breaks. The only source of fibrous debris for the AP1000 is from resident containment debris. As a result, the fiber debris available to transport to the recirculation screens as well as to the core is very low.

Recent tests performed for the AP1000 recirculation screens used debris loads (fiber, particulate and chemical) that bound those loads that would exist inside the AP1000 containment. Tests using these bounding debris loads resulted in an inconsequential head loss across the recirculation screen of about 1 inch of water. These test results are documented in WCAP-16914-P, "Evaluation of Debris Loading Head Loss Tests for AP1000 Recirculation Screens and In-Containment Refueling Water Storage Tank Screens," which was submitted to the NRC on March 3, 2008.

Similarly, bounding design basis debris loads were used to evaluate downstream effects on systems, structures and components in the passive heat removal (PXS) system flow path. A primary concern in this evaluation is the effect of this debris loading on the ability to maintain long term core cooling flow. The bounding design basis debris loads for the AP1000 are insufficient to form a contiguous fiber bed across the bottom of the core. The head loss correlation used in the downstream effects evaluation to perform scoping calculations of the head loss across the AP1000 screens and core is the NUREG/CR-6224 correlation.

As shown in APP-GW-GLR-079:

- There is insufficient fiber to form a continuous fiber bed on the bottom of the fuel. Without a continuous fiber bed, there will be "clean screen" area available on the bottom of the fuel.
- With clean screen area and small post-accident chemical product loading, post-accident chemical precipitants will not impair flow into the core.
- The resulting head loss at the bottom of the fuel is negligible.

Therefore, post accident and resident debris in the containment and the formation of post-accident chemical products in the AP1000 sump environment will not form a contiguous fiber bed. Without a contiguous fiber bed, the resident debris and post-accident chemical products will have no adverse impact

on the recirculation flow path of the PXS. Thus, the ACRS concerns related to the formation of a contiguous fiber bed at the core entrance are not applicable to the AP1000 design.

To provide an additional demonstration of post–LOCA long term core cooling, Westinghouse performed long-term core cooling sensitivity calculations using the WCOBRA/TRAC code and assuming large arbitrary, non-mechanistic, head losses for the containment recirculation and IRWST screens and to the core that bound the expected head losses. The flow resistance of the lower support plate at the core inlet was increased to model a pressure drop of 3 feet.

- This head loss value is highly conservative when compared to the calculated conclusion that there is insufficient fiber to form a contiguous fiber bed on the bottom of the fuel and small experimental head losses from the AP1000 recirculation screen testing results that used debris loads (fiber, particulate and chemical) that bound those loads that would exist inside the AP1000 containment. The recirculation screen tests performed using these bounding debris loads resulted in an inconsequential head loss across the recirculation screen of about 1 inch of water.
- The conservatism in the assumed 3 feet of head loss is also demonstrated in the measured head loss across a fuel assembly that has collected fibrous and particulate debris as submitted in response to Requests for Additional Information (RAI) on WCAP-16792-NP. While this testing did not include chemical effects, both the fibrous and particulate debris loading used in the test are far in excess of that evaluated for the AP1000. For the debris loading case tested that most closely but conservatively approximates the design basis debris loading at the core entrance for the AP1000 (3.62 ft^3 of fiber and 86.8 lb_m of particulate) the observed head loss was only 0.8 inches of water.

The WCOBRA/TRAC sensitivity calculations are documented in APP-PXS-GLR-001, "*Impact on AP1000 Post-LOCA Long Term Cooling of Postulated Containment Sump Debris.*" This report was submitted to the NRC on April 28, 2008 in letter DCP/NRC2127.

Another aspect of long term core cooling for the AP1000 is the potential deposition of chemical products on fuel following the high energy line break. The LOCADM spreadsheet calculation, described in WCAP-16793-NP, was used to evaluate the deposition of chemical products within the core. This methodology and all related RAI's received on the spreadsheet calculation were reviewed by the NRC in their draft SE on WCAP-16793-NP. The draft SE identified several conditions and limitations regarding the use of the LOCADM spreadsheet calculation to be addressed in the plant-specific application of that spreadsheet. The use of the LOCADM spreadsheet calculation was the only method from WCAP-16793-NP that was applied to the AP1000 design to demonstrate long-term core cooling.

The conditions and limitations of the draft Safety Evaluation for WCAP-16793-NP applicable to the LOCADM calculation are listed below:

- Assuming the peak local oxidation allowed by 10 CFR 50.46, or 17 percent of the cladding wall thickness without exception (Item 8),
- Not performing plant specific refinements to the WCAP-16530-NP base model that would reduce the chemical source term considered in the downstream analyses (Item 10),
- Not performing plant specific calculations to use a less conservative thermal conductivity value to calculate scale than that provided in WCAP-16793-NP [0.11 BTU/hr-ft-°F] (Item 11),
- Assuming the peak local oxidation allowed by 10 CFR 50.46, or 17 percent of the cladding wall thickness consistent with Conditions and Limitations item number 8 and assuming a crud

thickness of 127 microns, which is the thickest crud that has been measured at a modern PWR, as input to LOCADM (Item 12), and

- Applying a factor of two to the aluminum release to compensate for under-predicting the aluminum concentrations during the initial active corrosion period as witnessed in ICET Test 1. The total aluminum considered did not exceed the total predicted by the WCAP-16530-NP spreadsheet for 30 days (Item 13).

Westinghouse followed and incorporated these conditions and limitations into the LOCADM calculations performed for the AP1000 Standard Design. None of these conditions and limitations were the subject of concerns raised by the ACRS at the March 19, 2008 ACRS meeting regarding the WCAP-16793-NP methodology.

The concerns expressed in the March 19, 2008 ACRS meeting regarding the WCAP-16793-NP methodology focused on the collection of fibrous and particulate debris at the bottom of the fuel such that decay heat removal from the core might be challenged. For this condition to exist, a contiguous fiber bed must be formed at the core inlet or at fuel grids. As noted above, there is insufficient fiber in the AP1000 to form a contiguous fiber bed at the core inlet, or within the core itself. Therefore, since a contiguous fiber bed cannot be formed at the core inlet for the AP1000 Standard Design, the concerns expressed in the March 19, 2008 ACRS meeting regarding the WCAP-16793-NP methodology are not applicable to the AP1000 Standard Design.

The AP1000 Standard Design eliminates fibrous insulation debris by precluding the use of such materials in the regions of containment subject to damage from jets from postulated high energy line breaks and minimizes chemical effect products through design of the AP1000 containment itself.

The only method from WCAP-16793-NP that was applied to the AP1000 design was the LOCADM spreadsheet calculation. The application of the LOCADM method implemented the conditions and limitations of the NRC's draft SE for WCAP-16793-NP.

In summary, the long-term core cooling evaluations performed for the AP1000 Standard Design used portions of WCAP-16406-P-A and WCAP-16793-NP. These evaluations demonstrate that long-term core cooling for the AP1000 will be maintained following a postulated LOCA. As discussed above, the questions expressed in the March 19, 2008 ACRS meeting regarding the WCAP-16793-NP methodology are not applicable to the AP1000 Standard Design due to the lack of fibrous debris necessary to form a contiguous bed on the fuel. Furthermore, although not the subject of questions raised by ACRS, the application of the LOCADM spreadsheet calculation to demonstrate acceptable long-term core cooling was consistent with all applicable conditions and limitations identified by the NRC in their draft SE for WCAP-16793-NP.

This letter is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information provided in this report is generic and is expected to apply to all Combined Operating License (COL) applicants referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Questions or requests for additional information related to content and preparation of this information should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of letter.

Very truly yours,

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