AUDIT SUMMARY FOR REVIEW OF WCAP-17938, REVISION 1, "AP1000 IN-CONTAINMENT CABLES AND NON-METALLIC INSULATION DEBRIS INTEGRATED ASSESSMENT"

A. Location

The audit was conducted at the Westinghouse Electric Company (Westinghouse) Offices located in Rockville, Maryland. The audit supports development of a preliminary safety evaluation report and, if necessary, a request for additional information (RAI).

March–April 2016

Westinghouse Electric Company
11333 Woodglen Drive, Suite 202
Rockville, Maryland 20852
Telephone: 301-881-7040

B. Background

In September 2004, the staff issued NUREG-1793, "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design" (the FSER). The staff issued Supplement 1 to the FSER in December 2005 to address details related to rulemaking, and Supplement 2 to the FSER in September 2011 to address modifications proposed in the design certification amendment.

NUREG-1793 Supplement 2 contains the U.S. Nuclear Regulatory Commission (NRC) staff's evaluation of how the AP1000 design addresses Generic Safety Issue 191, "Assessment of Debris Accumulation on Pressurized-Water Sump Performance" (GSI-191), and Generic Letter 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design-Basis Accidents at Pressurized-Water Reactors" (GL 2004-02).

WCAP-17938, "AP1000 In-Containment Cables and Non-Metallic Insulation Debris Integrated Assessment," re-evaluates the AP1000 GSI-191 and GL 2004-02 debris assessment described in Revision 19 of the design control document. Specifically, WCAP-17938 assesses the potential for generation of debris from non-metallic insulation and materials in the reactor cavity (e.g., neutron shield blocks) and electrical cables in the containment.

As discussed in WCAP-17938, the AP1000 GSI-191 and GL 2004-02 debris evaluation result is that no fibrous debris is generated in a loss-of-coolant accident (LOCA). This is documented in APP-GW-GL-700 (Revision 19), "AP1000 Design Control Document," Subsection 6.3.2.2.7.1, which states "a LOCA in the AP1000 does not generate fibrous debris due to damage to insulation or other materials included in the AP1000 design." This is based on the use of metal reflective insulation or a suitable equivalent and the lack of fibrous insulation and other sources of fiber located in the LOCA jet impingement zones.

As discussed in WCAP-17938, the AP1000 plant design includes non-metallic insulation and materials in the reactor cavity that are designed to be a suitable equivalent to metal reflective insulation. Additionally, the AP1000 plant design includes in-containment electrical cabling that may contain fibrous and other materials (jackets, wrappings, and filler materials), which may be directly impinged upon by a jet of water from a LOCA. Neither of these items (i.e., encapsulated

non-metallic insulation and cabling) were considered in the applicants evaluation addressing GSI-191 and GL 2004-02 or the NRC staff's FSER (NUREG-1793 Supplement 2).

To address these items, Westinghouse developed a program to evaluate any potential impacts to the current licensing basis from the exposure of cables to direct jet impingement by water from a LOCA and to qualify encapsulated non-metallic insulation and materials as a suitable equivalent to metal reflective insulation. The purpose of the program was to define a cable zone of influence (ZOI) and to confirm that the encapsulated non-metallic insulation and materials meet the requirements of suitable equivalency and may be used in place of metal reflective insulation at discrete locations in the reactor cavity. The program included jet impingement testing of neutron shield blocks (e.g., encapsulated non-metallic insulation and materials) and cabling, and submergence testing of neutron shield blocks.

NRC staff determined it would be advantageous to audit documents that support WCAP-17938 Revision 1 evaluations and conclusions.

C. Audit Bases

This regulatory audit is based on the following:

- Title 10 *Code of Federal Regulations* (10 CFR), Appendix D to Part 52, "Design Certification Rule for the AP1000 Design"
- 10 CFR 50.46(b)(5), "Long-term cooling"
- General Design Criterion 35, "Emergency core cooling"
- General Design Criterion 38, "Containment heat removal"
- Standard Review Plan (SRP) Section 6.2.2 "Containment Heat Removal System"
- SRP Section 6.3, "Emergency Core Cooling System"
- Regulatory Guide 1.82, Revision 4, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident"

D. Audit Scope

The audit will focus on documents associated with achieving the stated purpose of WCAP-17938. The purpose of the topical report, as discussed in the WCAP-17938 introduction section, is to obtain NRC approval for the following:

- defining the zone of influence for water jet impingement on cabling as 4D, where D is the diameter of the postulated pipe break
- establishing that upper and lower neutron shielding and water inlet doors of the reactor vessel insulation system as well as neutron shield blocks of the CA31 module are equivalent to metal reflective insulation
- using an alternative methodology for defining debris generation break size for postulated accidents per Nuclear Energy Institute (NEI) 04-07 [1]

The staff will conduct this audit in accordance with the guidance provided in NRO-REG-108, "Regulatory Audits" (Reference 1).

E. Team Assignments

Clinton Ashley, NRO, Reactor Systems Engineer, Audit Team Lead
Gregory Makar, NRO, Materials Engineer
Boyce Travis, NRO, Reactor Systems Engineer
Yueh-Li (Renee) Li, NRO, Senior Mechanical Engineer
Malcolm Patterson, Reliability and Risk Analyst
Bruce Bavol, NRO, Project Manager

Other NRC staff members may be added as the need arises.

F. Summary

See attachments A, B, and C below.

ATTACHMENT A

Confined Jet Behavior and Debris Generation Break Size Determination

Purpose:

The purpose of this audit was to support the development of a preliminary safety evaluation report of the WCAP and, if necessary, a request for additional information (RAI). Specifically, the staff reviewed the information provided in the WCAP and the supporting documents to gain an understanding of the AP1000 debris assessment activities associated with confined jet behavior within the reactor vessel cavity and limited postulated break sizes including their associated zone of influence (ZOI) used in the Region II analysis.

Background:

As discussed in the WCAP, the AP1000 plant design includes non-metallic insulation (NMI) in the reactor vessel cavity that is designed to be a suitable equivalent to metal reflective insulation. The WCAP presents the methodology used in assessing the potential debris generation in the reactor vessel cavity resulting from postulated reactor coolant system (RCS) pipe breaks. Specifically, Section 3.5.4 of the WCAP provides information on a jet discharging in a confined space because NMI is located within the reactor vessel cavity and the reactor vessel cavity is a more confined space as compared to other regions in containment. In addition, Section 4.3 of the WCAP provides information on the Region II analysis used in determining the AP1000 debris generation break size. As part of this assessment, the WCAP assesses postulated main RCS pipe breaks and shows limited pipe displacement. The limited pipe displacement is then used to determine the equivalent break size and the associated ZOI for debris generation assessments.

Regulatory Basis:

- Title 10 Code of Federal Regulations (10 CFR), Appendix D to Part 52, “Design Certification Rule for the AP1000 Design”
- 10 CFR 50.46(b)(5), “Long-term cooling”
- General Design Criterion 35, “Emergency core cooling”
- General Design Criterion 38, “Containment heat removal”
- Standard Review Plan (SRP) Section 6.2.2 “Containment Heat Removal System”
- SRP Section 6.3, “Emergency Core Cooling System”
- Regulatory Guide 1.82, Revision 4, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident”

Audit Date and Location:

March 16-17 and 29-30; 2016, Westinghouse Electric Company, 11333 Woodglen Drive Suite 202, Rockville, Maryland

Audit Team Members:

Renee Li

Westinghouse Electric Company Participants (all on March 29-30, 2016):

A. Pfister	(AP1000 Engineering)
T. Kindred	(AP1000 Engineering)
S. Sinha	(AP1000 Licensing)

Describe the Audit Activities:

The audit activities described in this attachment focused on the confined jet behavior within the AP1000 reactor vessel cavity and the limited pipe displacement used in the Region II analysis. As discussed above, the WCAP provides information on the confined jet behavior because NMI is located within the reactor vessel cavity and the reactor vessel cavity is a more confined space as compared to other regions in containment. In addition, the WCAP uses Region II analysis in assessing the potential debris generation resulting from the postulated RCS main loop pipe breaks. The Region II analysis allows for more realistic analytical methods and assumptions such as limited pipe displacement. The WCAP proposes that if a structural evaluation of the RCS main loop piping shows limited pipe displacement will occur, then an equivalent break diameter for the limited separation break may be used to determine the ZOI for the Region II analyses.

To support the review of the WCAP Region II analysis, the staff reviewed (during March 16-17 audit) the information included in the following two non-docketed Westinghouse calculation notes (References 4-6 and 4-7 of the WCAP):

- APP-PL01-P0C-002, Revision 0, Pipe Reaction Force Determination for Large Break LOCA
- APP-PL01-P0C-003, Revision 0, RCL Pipe Movement in Large Break LOCAs

The purpose of the APP-PL01-P0C-002 calculation is to document the methodology used for calculating the pipe reaction forces for the AP1000 loop piping resulting from a double ended guillotine break of the hot leg and cold leg loop piping. The calculation of the pipe reaction forces were then provided as inputs to a non-linear structural analysis performed in APP-PL01-P0C-003 to determine mechanistically the amount of pipe displacement that would occur resulting from a double-ended rupture of AP1000 reactor coolant system loop piping. APP-PL01-P0C-003 calculation note presents the methodologies and results for determining the pipe movement for five postulated RCS double-guillotine breaks as identified Section 4.3 of the WCAP.

In addition, during the audit on March 29-30, 2016, the staff discussed with Westinghouse the issues identified related to the confined jet behavior and Region II analysis. These issues are identified below in a format that supports generating a request for additional information to the applicant (see RAI numbers ICC&NMI – 013 to – 028 contained in Agencywide Documents Access and Management System (ADAMS) Accession No. ML16133A195).

A. Confined Jet Behavior Areas of Concern pertaining to Section 3.5.4 of the WCAP:

1. The applicant is to explain/define the jet surface characteristics referred on the top of page 3-57 of the WCAP. (ICC&NMI – 013)

2. The applicant is to clarify the statements regarding pressure coefficient on page 3-60 of the WCAP. On the top of this page, it states that the pressure coefficient is approximately unity for AP1000 plant X'/D of [ ]; while at the bottom of the page, it states that the pressure coefficient is approximately zero for AP1000 plant X'/D of [ ]. (ICC&NMI – 014)

3. The applicant is to explain/justify the relevance of showing the red vertical line [ ] on Figure 3-67(a) in the WCAP. Note the pressure coefficient as shown on the figure is on the impingement plate (corresponding to reactor vessel (RV) boundary for the AP1000 plant configuration). However, the NMI in the

AP1000 plant is [ ]. The applicant is also to explain/clarify from the Reference 3-17 testing results how the jet pressure field is analogous to that of the free jet for the AP1000 plant. Specifically, the applicant is to clarify whether the Reference 3-17 testing results are only applicable to the RV boundary as the impingement plate in AP1000 plant configuration. If this also applies to the jet pressure field in the region of NMI such that the jet pressure field in the NMI region is also analogous to that of the free jet, the applicant is to justify this conclusion. Similar comment is also applicable to other figures included in this section of the WCAP. (ICC & NMI – 015)

4. The applicant is to explain/clarify the statement that the flow deflects about a jet diameter above the impingement plate for a confinement of X'/D<2 (page 3-60) including its implications of the jet flow for the AP1000 configuration. (ICC & NMI – 016)

5. The applicant is to explain/justify the statement that the pressure coefficient of the confinement of X'/D=6 corresponds to that of free jet (page 3-61). Similar to Question 3 above, the applicant is also to clarify the statement that for the AP1000 plant confinement ratio of [ ], this implies the jet pressure field is analogous to that of the free jet. Specifically, the applicant is to clarify whether the referred jet pressure field is the local impingement plate pressure as defined per Equation 3-1 on page 3-60 of the WCAP. The applicant is to explain/justify whether the pressure in other jet regions as shown on page 3-55 of the WACP is also analogous to that of the free jet. In addition, the staff noted that in 4th paragraph on page 3-71 of the WCAP, the applicant concludes that the comparison to the jet pressure distribution as conveyed in multiple literatures showed for the AP1000 plant-specific confinement ratio that the confined plate and impingement plate pressure distribution were analogous with that of the free jet. Similar to the Questions 3 above, the applicant is requested to make it clear regarding the specific jet region for which the pressure distribution were analogous to the free jet in the WCAP. In addition, the applicant is to address the staff's concern on the pressure field for the NMI, which is [ ] (i.e., the impingement plate). (ICC & NMI – 017)

6. The applicant is to explain/clarify the relevance of Figure 3-69 (page 3-63) to AP1000 plant confinement. The figure is not clear (i.e., the correlations are not readily apparent and the terms shown in the figure are not defined). The staff also noted that the confinement ratio shown in the figure ranged from 0.25 to 1.0, which does not encompass the geometric confinement [ ] of the AP1000 plant configuration. (ICC & NMI – 018)

7. The applicant is to explain/clarify the definition of unconfined (normal) jet referred in Figure 3-72 (page 3-66) in the WCAP. (ICC & NMI – 019)

8. The applicant is to explain/clarify the second sentence in the first paragraph on page 3-72. It states that the NMI would probably experience a [ ]. The staff noted that Figure 3-77 in the WCAP shows the ratio of the velocity profile of a Region IV

jet and a free jet emitting radially from a jet source. Based on the comparison, the applicant concluded [

] Furthermore, the applicant is to explain/clarify Figure 3-77 including the definition of the terms in the equations included in the figure, the assumptions used, the application of NUREG/CR-2913, "Two-Phase Jet Loads," and how they are relevant to the AP1000 plant condition/configuration. (ICC & NMI – 020)

9. As a general comment, some figures included in this section of the WCAP are not clear. For example, the reproduction quality of some figures makes it difficult to read the information. In addition, for some figures, the correlations are not readily apparent. Moreover, the coordinate and the parameter/term shown on some figures were not clearly defined. (ICC & NMI – 021)

B. Region II Analysis Areas of Concern Pertaining to Section 4.3 of the WCAP:

1. Section 4.3 of the WCAP states that if no piping analyses have been performed for the RCS main loop piping application, then a doubled-ended guillotine break (DEGB) assuming the full hot leg or cold leg pipe inner diameter must be evaluated; however, other reasonable best estimate assumptions may still be employed in the analysis (page 4-5 of the WCAP). The applicant is to explain/identify other reasonable best estimate assumptions, which may be employed in the analysis. (ICC & NMI – 022)

2. As indicated in Section 4.3.2 of the WCAP, the geometry of a limited separation break is discussed in ANSI/ANS 58.2-1988 (Reference 4-4 of the WCAP). The jet geometry of circumferential break with limited separation is shown in Figures 4-1 and 4-2 of the WCAP. It should be noted that Reference 4-4 defines a limited separation break as having an axial displacement of less than or equal to 0.5 diameter and a lateral displacement of less than or equal to the pipe wall thickness. However, the applicant indicates that this definition is extended for the purpose of AP1000 Region II analyses to include lateral displacements greater than the pipe wall thickness and up to 1 diameter. The staff also noted that Section 4.3.2.2 of the WCAP provides an equation for the equivalent diameter of such a limited separation break, [

]. The applicant is to explain/justify the extension of Reference 4-4 definition of a limited separation break, the jet geometry for such a limited separation break, and the basis of the equations provided in Section 4.3.2.2 of the WCAP. (ICC & NMI – 023)

3. Section 4.4.3 of the WCAP states that the hot leg and cold leg displacement results from the ANSYS LS-DYNA analysis presented in Table 4-1 may be used to support the AP1000 plant Region II debris source term calculations in addition to any best estimate assumptions that are deemed reasonable for the individual analysis. The applicant is to explain/identify the reasonable best estimate assumptions, which may be used to support the AP1000 plant Region II analysis. (ICC & NMI – 024)

4. Section 4.4.3 of the WCAP describes a qualitative method of comparing the circumferential break jet expansion geometries with limited separation to the full separation DEGB jet expansion geometry. It also describes a simplified volumetric comparison using the methodology outlined in Appendix C of Reference 4-4 of the WCAP. In addition, Figure 4-8 of the WCAP shows the jet geometries including Regions 1 and 2 and up to the asymptotic plane for limited separation (Figure A) and full separation (Figure B). The staff noted that the jet geometry as shown in Figure A is for a limited separation with an axial displacement less than or equal to 0.5 diameter and a lateral displacement less than or equal to the pipe wall thickness as defined in Reference 4-4. However, as noted in Section 4.3.2 of this WCAP, this definition is extended for the purpose of AP1000 Region II analyses to include lateral displacements greater than the pipe wall thickness and up to 1 diameter. The applicant is to explain/show the jet geometry for a limited separation break configuration with the lateral displacement being greater than the pipe wall thickness and up to 1 diameter. In addition, the applicant is to explain how the jet volume for this type of jet geometry will be determined and used in the comparison to the jet volume to that of twice the fully separated jet in the Region II analysis. (ICC & NMI – 025)

5. Section 4.4.3.1.2 of the WCAP states that [

   ]. The applicant is to clarify the discrepancy [
   ].
   (ICC & NMI – 026)

6. Section 4.4.3.1.3 of the WCAP (page 4-18) refers to Subsections 4.3.1.1 and 4.3.1.2 of the WCAP. In addition, Section 4.4.3.2.4 (page 4-20) refers to Subsections 4.3.2.2 and 4.3.2.3 of the WCAP. In addition, Section 5.1.3 (page 5-16) and Section 7 (page 7-1) both refer to Subsection 3.5.3.3 of the WCAP. It appears that the referred subsection numbers are in error as there are no Subsections 4.3.1.1, 4.3.1.2, 4.3.2.2, 4.3.2.3, and 3.5.3.3 in the WCAP. The applicant is to clarify the above referred subsection numbers. (ICC & NMI – 027)

7. For some Region II analyses described in the WCAP, the applicant took credit for intervening structures such that the ZOI volume is truncated by the intervening structures. For example, in Section 5.1.1.1.5.2 the applicant states that [

   ]. Therefore, for the Region II analysis, the ZOI was truncated [ ]. The applicant is to clarify that all the intervening structures credited in the AP1000 plant Region II analyses are adequately designed to accommodate the applicable LOCA jet loads. (ICC & NMI – 028)

Describe the Closing or Exit Briefing:

Based on the review/audit of the information described in the WCAP and the supporting documents, the staff determined that the Westinghouse technical approaches, as presented, are generally reasonable. The NRC staff also stated that Region II analysis as described in NEI-04-07 has been previously reviewed and approved by the NRC staff. However, the NRC staff determined that additional information or clarification was needed to complete the review of the confined jet behavior and Region II analysis. As indicated above, the NRC staff discussed with Westinghouse the issues identified as well as Westinghouse's plans to address these issues. At the close of the audit, Westinghouse indicated that they understood the staff concerns. Westinghouse plans to address the staff concerns as part of the RAI process. NRC staff indicated that a second phase audit is optional, but may be needed to address follow-up RAIs and support completion of the advanced safety evaluation.

Deviations from the Audit Plan:

None

ATTACHMENT B
Chemical Effects

Purpose:

Chemical effects refers to the potential interactions between materials in containment and the post-LOCA recirculating fluid to generate substances that could impede the flow of water through the sump strainers or fuel assemblies, or affect the functionality of downstream components. The purpose of this audit activity was to support the development of the staff's preliminary safety evaluation report on WCAP-17938 and help identify the need for additional information the staff would need to complete its review.

Background:

The existing chemical effects evaluation for the AP1000 is based on a methodology that considers specific chemical substances generated according to the types of submerged materials and the conditions in the post-LOCA recirculating fluid (temperature and pH). The proposed shielding and insulation materials have the potential to generate additional chemical precipitates if submerged in the post-LOCA fluid. Supporting documents that the staff audited contained information necessary for assessing the potential for additional chemical effects from the proposed materials. The audited documents include details about the submergence testing of the proposed materials in different configurations and how the test results were integrated into the existing chemical effects analysis, including sensitivity studies for certain parameters.

Regulatory Basis:

- Title 10 Code of Federal Regulations (10 CFR), Appendix D to Part 52, "Design Certification Rule for the AP1000 Design"
- 10 CFR 50.46(b)(5), "Long-term cooling"
- General Design Criterion 35, "Emergency core cooling"
- General Design Criterion 38, "Containment heat removal"
- Standard Review Plan (SRP) Section 6.2.2 "Containment Heat Removal System"
- SRP Section 6.3, "Emergency Core Cooling System"
- Regulatory Guide 1.82, Revision 4, "Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident"

Audit Date and Location:

March 24, 29, 30 and April 1, 4, 8, 2016 ─ Westinghouse Electric Company, 11333 Woodglen Drive Suite 202, Rockville, Maryland

Audit Team Members:

Greg Makar

Westinghouse Electric Company Participants:

A. Pfister	(AP1000 Engineering)
T. Kindred	(AP1000 Engineering)
K. McNamee	(AP1000 Engineering)
S. Sinha	(AP1000 Licensing)

List of Audited Documents

- CA31 Neutron Block Details, E&DCR No. APP-CA31-GEF-005, Rev. 0, final signature 5/30/2013.
- AP1000 GSI-191 Chemistry Effects Evaluation, APP-PXS-M3C-052, Rev. 3, final signature 3/2/2015.
- Aluminum Inventory for AP1000 Containment, APP-PXS-M3C-221, Rev. 0, final signature 10/21/2014.
- AP1000 Insulation Submergence Testing, TR-CCOE-14-02, Rev. 0, November 2014.
- AP1000 Design Change Proposal APP-GW-GEE-4911, Rev. 0, Requested Completion Archive Date: 12/23/2014, [ ] RV Insulation Neutron Shielding."

Describe the Audit Activities:

The audit activities described in this attachment focused on the potential for the proposed materials to contribute to the calculated chemical precipitate in the post-LOCA recirculating fluid. Since these materials are encapsulated in stainless steel, which does not contribute to chemical effects, the additional chemical effects would be determined by whether there is communication between the fluid and the encapsulated materials, and by the amount of elemental release into the fluid. The effect of the additional release from the materials proposed in WCAP-17938 depends, in part, on the amount and type of other contributing materials assumed to be in the pool according to the design basis chemical effects analysis. With little calcium in the current design and proposed materials, the most significant elements potentially contributing to chemical effects are aluminum and silicon. The audit included examination of documents on March 24, April 1, April 4, and April 8, 2016, as well as discussions with Westinghouse March 29-30, 2016. In addition, the staff had a phone call with Westinghouse on May 4, 2016, to clarify requests for additional information (RAIs).

Summary of the Discussion with Westinghouse March 29-30, 2016

1. Staff requested clarification on whether the water inlet doors or CA31 shield blocks have inner foil encapsulation (WCAP Subsections 2.2.1 and 2.2.4). Westinghouse confirmed there is no foil in these doors and blocks.
2. Staff asked for any additional details about [ ] and any analyses or test of their functionality (WCAP Subsections 2.2.2-2.2.4). Westinghouse referred the staff to a design document available for audit that contains some discussion on this topic.
3. Staff requested explanation of how Table 3-12 was constructed. Westinghouse provided the explanation and referred the staff to the submergence test report. The staff confirmed the explanation later in auditing the test report.
4. Staff requested clarification on the [ ] in the submergence test program (WCAP Subsection 3.6.2.4) and how the filtration tests distinguished between [ ]. Westinghouse referred the staff to the submergence test report, which was available for audit. The staff was still unclear after auditing the report and as a result, the staff issued RAI ICC & NMI – 031, contained in ADAMS Accession No. ML16133A195.
5. Staff noted that the WCAP evaluates a reduced aluminum content relative to the AP1000 certified design but is not proposing to change the Design Control Document (WCAP Subsection 5.1.3). Staff asked how a reduced aluminum limit is being implemented. Westinghouse replied that licensee FSAR changes would address this. After auditing the chemical effects analysis, the staff requested clarification on the

aluminum limitations in RAI ICC&NMI – 035, contained in ADAMS Accession No. ML16133A195.

6. Staff asked how the submergence test results were used in the WCAP-16530 analysis. Westinghouse referred the staff to the chemical effects calculation note. The staff found the information later in auditing the calculation note.

Summary of the Document Review

The documents examined in this part of the audit provide details about how the neutron shield blocks are made, how the submergence tests were performed and evaluated, and how the results of those tests were integrated with the existing AP1000 chemical effects analysis. The methodology used in the existing AP1000 analysis assumes a certain quantity of material exposed to the fluid and pre-determined elemental release rates, but the submergence tests measured the elements released. The audited documents showed how these results were used in the chemical effects methodology. In addition, since all aluminum released into solution is assumed to form a precipitate, the audit included a document identifying the inventory procedures and results for aluminum sources procured during construction of AP1000 units. Overall, the staff observed portions of the WCAP that require clarification. These observations were turned into requests for additional information ICC & NMI – 029 through 032 and – 034, contained in ADAMS Accession No. ML16133A195.

In summary, the document review portion of the chemical effects audit mainly included the following technical areas:

- Fabrication details for the neutron shield blocks
- Details of the submergence test procedures and results
- Assumptions made in calculations of chemical precipitate mass
- How the submergence test results were used in the methodology for calculating chemical precipitate mass
- The sensitivity cases considered for calculations of chemical precipitate mass
- The procedures and results of the aluminum construction inventory

Describe the Closing or Exit Briefing:

The NRC staff summarized the issues. Westinghouse indicated that they understood the staff's concerns. Westinghouse plans to address the staff's concerns as part of the RAI process. NRC staff indicated that a second phase of auditing is optional, but may be needed to address follow-up RAIs and support completion of the advanced safety evaluation. In a phone call on May 4, 2016, the staff provided clarifying information to Westinghouse regarding the staff's RAIs related to chemical effects.

Deviations from the Audit Plan:

None

ATTACHMENT C
Jet Impingement

Purpose:

Debris assessment activities related to jet impingement testing

Background:

As part of WCAP-17938-P (referred to hereafter as WCAP), the applicant identified the need for testing in order to better understand the effects of jet impingent on materials with respect to debris production. During the development of the WCAP, the applicant conducted jet impingement testing on cables and neutron shield blocks. NRC staff witnessed some of the testing, and observations from the testing are summarized in ADAMS Accession Nos. ML14289A257 and ML15238B546. WCAP Section 3 describes the jet impingement test program, which was designed to establish the neutron shield blocks as a suitable equivalent to metal reflective insulation (MRI) (with respect to debris production) and establish a ZOI for cables.

Regulatory Basis:

- Title 10 Code of Federal Regulations (10 CFR), Appendix D to Part 52, “Design Certification Rule for the AP1000 Design”
- 10 CFR 50.46(b)(5), “Long-term cooling”
- General Design Criterion 35, “Emergency core cooling”
- General Design Criterion 38, “Containment heat removal”
- Standard Review Plan (SRP) Section 6.2.2 “Containment Heat Removal System”
- SRP Section 6.3, “Emergency Core Cooling System”
- Regulatory Guide 1.82, Revision 4, “Water Sources for Long-Term Recirculation Cooling Following a Loss-of-Coolant Accident”

Audit Date and Location:

March 15, 16 and 29-30 and April 4, 2016 ─ Westinghouse Electric Company, 11333 Woodglen Drive Suite 202, Rockville, Maryland

Audit Team Members:

Boyce Travis and Clint Ashley

Westinghouse Electric Company Participants:

A. Pfister	(AP1000 Engineering)
T. Kindred	(AP1000 Engineering)
S. Sinha	(AP1000 Licensing)

Documents Audited:

- WCAP-17617, Volumes 1 and 2, "Jet Impingement Testing of AP1000 In-containment Cables," November 2014
- WCAP-17616, "Jet Impingement Testing of AP1000 Reactor Vessel Insulation System Neutron Shielding Blocks," November 2014

- APP-MN20-V2-101, “RV Bottom Head Insulation Layout RBH1”
  Sheet 1 of 1, Revision 1, dated April 5, 2011
- APP-MN20-V2-150, “RV Upper Neutron Shielding”
  Sheet 1 of 1, Revision 1, dated April 5, 2011
- APP-MN20-V2-148, “RV Lower Neutron Shielding”
  Sheet 1 of 1, Revision 1, dated April 5, 2011
- APP-CA31-GEF-005, “CA31 Neutron Block Details”
  39 pages, Revision 0, dated May 29, 2013
- APP-GW-GEE-4911,[ ] RV Insulation Neutron Shielding,”
  pages 1 to 14, Revision 0, approved January 15, 2015

Describe the Audit Activities:

March 15 and 16, 2016:

As part of the audit, staff reviewed a selection of documents referenced in Sections 2 and 3 of the WCAP, including neutron shield block details, water inlet door details, test reports for both the cable testing and the neutron shield block testing, and test procedures and data from the testing lab.

To better understand the basic design and confirm the information provided in the WCAP with respect to the neutron shield blocks and water inlet doors, the staff audited the following documents referenced in WCAP-17938-P, Revision 1.

APP-MN20-V2-101: (WCAP Section 2.2.1 and associated Reference 2-11)

The WCAP describes the water inlet doors as made of [

].
The NRC staff was not able to confirm the WCAP’s water inlet doors description based upon a review of the referenced drawing. For example, 1) the drawing for the water inlet doors shows construction using only [ ]; 2) the drawing for the water inlet doors does not indicate [ ]; and 3) the drawing for the water inlet doors does not indicate [ ]. Because the drawing provides information that conflicts with the description of the water inlet doors provided in the WCAP [ ] and appears to be missing other important design details [ ], the staff requested that the applicant provide documentation to confirm the WCAP description for the water inlet doors. To address this concern, the staff issued a request for additional information ICC & NMI – 007 contained in ADAMS Accession No. ML16133A195.

APP-MN20-V2-150 (WCAP Subsection 2.2.2 and associated reference 2-12):

WCAP Subsection 2.2.2 describes the upper neutron shield (UNS) as consisting of [
]. The NRC staff was not able to confirm a portion of the UNS description provided in the WCAP. For example, the drawing states that the UNS is constructed using [ ]. Because the drawing provides information that conflicts with the UNS description provided in the WCAP [ ], the staff requested that the applicant explain the apparent

conflict between the WCAP description and the referenced drawing. This issue is addressed as part of the *March 29-30, 2016,* and *April 4, 2016*, audit activity discussed below.

APP-MN20-V2-148 (WCAP Subsections 2.2.3, 3.1, and associated reference 2-13):

WCAP subsection 2.2.3 describes the lower neutron shield (LNS) as consisting of [ ]. WCAP Subsection 3.1 describes that LNS is constructed with [ ] stainless steel. The NRC staff was not able to confirm a portion of the LNS description provided in the WCAP. For example, the drawing states that the LNS is constructed using [ ]. Because the drawing provides information that conflicts with the LNS description provided in the WCAP [ ], the staff requested that the applicant explain the apparent conflict between the WCAP description and the referenced drawing. This issue is addressed as part of the *March 29-30, April 4* audit activity discussed below.

APP-CA31-GEF-005 (WCAP Subsections 2.2.4 and associated reference 2-14):

WCAP subsection 2.2.4 describes the CA31 neutron shielding boxes. The boxes are made of [ ]. The staff was able to confirm the WCAP CA31 neutron shield block description.

As part of the review of the test reports (provided in documents audited section above), staff found language that indicated that [

], but the test is deemed acceptable and included as part of the justification for the adequacy of the blocks. As a result, staff issued a request for additional information, ICC&NMI – 004, contained in ADAMS Accession No. ML16133A195.

March 29-30 and April 4, 2016:

The NRC staff audit activity on March 29-30, 2016 included applicant (Westinghouse) personnel to discuss NRC questions and observations associated with the WCAP and the material audited in the referenced documents listed above. Staff observed portions of the WCAP that require clarification. These observations were turned into requests for additional information ICC & NMI – 001, – 002, – 005, – 006, and – 008 to – 012, contained in ADAMS Accession No. ML16133A195. Additionally, staff discussed the role of the testing conducted at [ ] in the WCAP. As it currently stands, the testing is discussed in the report, but no firm conclusions are drawn by the applicant. As a result, to address this concern, the staff issued a request for additional information ICC&NMI – 003 contained in ADAMS Accession No. ML16133A195.

Staff asked the applicant to explain the behavior associated with minor variability in test pressure following the initial blowdown in the test facility, especially when compared with previous tests. Applicant personnel explained that the facility test reservoir was designed to sustain approximately [ ]. This maintained a conservative blowdown with respect to the plant; this is generally seen as a flat pressure following the first few seconds of the blowdown, but can sometimes result in [ ]. Ultimately, the effect is small ([ ]) and the behavior in each of the tests bounds the expected blowdown in the AP1000 plant because no mechanism exists to sustain the pressure,

and thus the test pressures are conservative. Staff also confirmed that the test facility report matched the descriptions provided in the WCAP as well as observations made by the staff during visits to the test facility in 2014 and 2015.

The staff and the applicant discussed limits of applicability for the WCAP. In particular, the applicant explained that the WCAP conclusions are applicable to AP1000 plants with cable and non-metallic insulation designs described in the WCAP and that they are not intended for any other designs.

With respect to the neutron shield blocks concerns discussed above as part of the March 15 and 16, 2016, audit activity, the applicant provided document APP-GW-GEE-4911. On April 4, the staff audited APP-GW-GEE-4911 (a design change package). The document approved a design change to the thickness of the [ ]. Therefore, the applicant addressed the concern identified for the UNS and LNS described above in the March 15 and 16, 2016, audit activity.

Describe the Closing or Exit Briefing:

The NRC staff summarized the issues. Westinghouse indicated that they understood the staff concerns. Westinghouse plans to address the staff concerns as part of the RAI process. NRC staff indicated that a second phase of auditing is optional, but may be needed to address follow-up RAIs and support completion of the advanced safety evaluation.

Describe Deviations from the Audit Plan:

None