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Docket Nos.: 50-424
50-425

NL-17-2044

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D. C. 20555-0001

Vogtle Electric Generating Plant- Units 1&2
Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10)

Ladies and Gentlemen:

By letter dated April 21, 2017 (Agencywide Documents Access and Management System Accession No. ML17116A098) as supplemented by letter dated July 11, 2017 (ADAMS Accession No. ML17192A245), Southern Nuclear Operating Company, Inc. (SNC) submitted a plant-specific technical report for Vogtle Electric Generating Plant, Units 1 and 2 and requested U.S. Nuclear Regulatory Commission (NRC) approval of the methods and inputs described in the technical report. The plant-specific technical report describes a risk-informed methodology to evaluate debris effects with the exception of in-vessel fiber limits. By letter dated November 15, 2017, the NRC staff notified SNC that additional information is needed for the staff to complete their review. The Enclosures provide the SNC response to the NRC requests for additional information.

The enclosed responses contain proprietary information as defined by 10 CFR 2.390. Westinghouse Electric Company LLC ("Westinghouse"), as the owner of the proprietary information, has executed the enclosed affidavit, which identifies that the enclosed proprietary information has been handled and classified as proprietary, is customarily held in confidence, and has been withheld from public disclosure. The proprietary information was provided to SNC in a Westinghouse transmittal which included the affidavit included in Enclosure 3. The proprietary information has been faithfully reproduced in the enclosed documentation, such that, the affidavit remains applicable. Westinghouse hereby requests that the enclosed proprietary information provided in Enclosure 1 to this letter be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390. A non-proprietary version of the RAI responses is provided as Enclosure 2.

This letter contains no NRC commitments. If you have any questions, please contact Ken McElroy at 205.992.7369.

Enclosure 1 to this letter contains Proprietary Information to be withheld from public disclosure per 10 CFR 2.390. When separated from Enclosure 1 this transmittal document is decontrolled

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NRR

I declare under penalty of perjury that the foregoing is true and correct. Executed on the
__2__ day of January 2017.

Respectfully submitted,

SOUTHERN NUCLEAR OPERATING COMPANY

J. J. Hutto
Director, Regulatory Affairs
Southern Nuclear Operating Company

JJH/PDB/CBG

Enclosures:

1. SNC Response to NRC Request for Additional Information (RAIs) - PROPRIETARY VERSION
2. SNC Response to NRC Request for Additional Information (RAIs) NON-PROPRIETARY VERSION
3. CAW-17-4687, "Application for Withholding Proprietary Information from Public Disclosure," (Non-Proprietary)

cc: Regional Administrator, Region II
NRR Project Manager – Vogtle 1 & 2
Senior Resident Inspector – Vogtle 1 & 2
State of Georgia Environmental Protection Division
RType: CVC7000

Vogtle Electric Generating Plant Unit 1 and 2
Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10)

Enclosure 3

CAW-17-4687, "Application for Withholding Proprietary Information from Public Disclosure," (Non-Proprietary)

Westinghouse

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CAW-17-4687

December 18, 2017

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Vogtle Electric Generating Plant - Units 1 & 2, "Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10) (Proprietary)"

The Application for Withholding Proprietary Information from Public Disclosure is submitted by Westinghouse Electric Company LLC ("Westinghouse"), pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Nuclear Regulatory Commission's ("Commission's") regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary information for which withholding is being requested in the above-referenced report is further identified in Affidavit CAW-17-4687 signed by the owner of the proprietary information, Westinghouse. The Affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.390 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying Affidavit by Southern Nuclear Company (SNC).

Correspondence with respect to the proprietary aspects of the Application for Withholding or the Westinghouse Affidavit should reference CAW-17-4687and should be addressed to James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 2 Suite 259, Cranberry Township, Pennsylvania 16066.

James A. Gresham, Manager
Regulatory Compliance

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

I, James A. Gresham, am authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC ("Westinghouse") and declare that the averments of fact set forth in this Affidavit are true and correct to the best of my knowledge, information, and belief.

Executed on: 12/18/17

[signature]
James A. Gresham, Manager
Regulatory Compliance

(1) I am Manager, Regulatory Compliance, Westinghouse Electric Company LLC ("Westinghouse"), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Nuclear Regulatory Commission's ("Commission's") regulations and in conjunction with the Westinghouse Application for Withholding Proprietary Information from Public Disclosure accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitute Westinghouse policy and provide the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of

Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

(iii) There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iv) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, is to be received in confidence by the Commission.

(v) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(vi) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in "Vogtle Electric Generating Plant - Units 1 & 2, 'Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10) (Proprietary),' " for submittal to the Commission. The proprietary information as submitted by Westinghouse is that associated with resolution of and response to NRC Generic Letter 2004-02 and may be used only for that purpose.

(a) This information is part of that which will enable Westinghouse to provide commercial support for resolution of and response to NRC Generic Letter 2004-02.

(b) Further this information has substantial commercial value as follows:

(i) Westinghouse plans to sell the use of similar information to its customers for the purpose of providing support for response to and resolution of NRC Generic Letter 2004-02.

(ii) Westinghouse can sell support and defense of industry guidelines and acceptance criteria for plant-specific applications.

(iii) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

Proprietary Information Notice

Transmitted herewith are proprietary and non-proprietary versions of a document, furnished to the NRC associated with response to and resolution of NRC Generic Letter 2004-02 and may be used only for that purpose.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the Affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

Copyright Notice

The reports transmitted herewith each bear a Westinghouse copyright notice. The NRC is permitted to make the number of copies of the information contained in these reports which are necessary for its internal use in connection with generic and plant-specific reviews and approvals as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.390 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by Westinghouse, copyright protection notwithstanding. With respect to the non-proprietary versions of these reports, the NRC is permitted to make the number of copies beyond those necessary for its internal use which are necessary in order to have one copy available for public viewing in the appropriate docket files in the public document room in Washington, DC and in local public document rooms as may be required by NRC regulations if the number of copies submitted is insufficient for this purpose. Copies made by the NRC must include the copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

Letter for Transmittal to the NRC

The following paragraphs should be included in your letter to the NRC Document Control Desk:

Enclosed are:

1. Vogtle Electric Generating Plant - Units 1 & 2, "Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10) (Proprietary)"
2. Vogtle Electric Generating Plant - Units 1 & 2, "Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10) (Non-Proprietary)"

Also enclosed are the Westinghouse Application for Withholding Proprietary Information from Public Disclosure, CAW-17-4687, accompanying Affidavit, Proprietary Information Notice, and Copyright Notice.

As Item 1 contains information proprietary to Westinghouse Electric Company LLC ("Westinghouse"), it is supported by an Affidavit signed by Westinghouse, the owner of the information. The Affidavit sets forth the basis on which the information may be withheld from public disclosure by the Nuclear Regulatory Commission ("Commission") and addresses with specificity the considerations listed in paragraph (b)(4) of Section 2.390 of the Commission's regulations.

Accordingly, it is respectfully requested that the information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the copyright or proprietary aspects of the item listed above or the supporting Westinghouse Affidavit should reference CAW-17-4687 and should be addressed to James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 2 Suite 259, Cranberry Township, Pennsylvania 16066.

Vogtle Electric Generating Plant Unit 1 and 2
Systematic Risk-Informed Assessment of Debris Technical Report SNC Response to NRC Request for Additional Information (RAIs #4-10)

Enclosure 2

SNC Response to NRC Request for Additional Information (RAIs) NON-PROPRIETARY VERSION

NRC RAI 4

As shown on Page E5-172 of Enclosure 5 to the letter dated April 21, 2017, the strainer tests head loss stabilization criteria appeared to allow for head loss to be increasing at debris addition points and at test termination. The head loss value at the end of the test is extrapolated to account for increases that were occurring when the test was terminated. For the full load debris test of record, the head loss from calcium phosphate precipitate addition appears to be increasing when the first batch of sodium aluminum silicate precipitate is added. The VEGP chemical effects evaluation may not include head loss from aluminum based precipitates until 24 hours.

Please describe how the extrapolation of the calcium phosphate precipitate induced head loss, to the point where aluminum precipitate head loss is considered, affects the analysis.

SNC Response to RAI 4

As stated in the Response to 3.f.10 in Enclosure 5 of the VEGP submittal, a head loss extrapolation constant of 3.89 ft was applied after 7.5 hours following the accident to account for the slight increase in head loss after meeting the stabilization criteria during testing (Reference 1 pp. E5-80 to E5-81). Table 3.g.16-1 in Enclosure 5 of the submittal shows strainer head losses evaluated for various sump conditions (Reference 1 pp. E5-103). As shown in that table, the extrapolation constant was applied to the calcium phosphate debris head loss before the formation of aluminum precipitate (see head losses at sump temperatures of 153°F and 140°F).

Before 7.5 hours, no extrapolations are necessary because the full debris load test, from which the head loss results were obtained, lasted for over 48 hours from the start of introduction of conventional debris to the end of head loss stabilization after adding the calcium phosphate debris (see Figures 3.o.2.17-2 and 3.o.2.17-3 in Enclosure 5 of the submittal (Reference 1 pp. E5-172)). Even the test duration for the addition of calcium phosphate debris and head loss stabilization alone is close to 24 hours (see Figures 3.o.2.17-2 and 3.o.2.17-3 in Enclosure 5 of the submittal (Reference 1 pp. E5-172)). Therefore, any potential head loss increases before 7.5 hours following the accident were captured by the recorded head loss data from testing. As a result, no additional extrapolation is necessary.

NRC RAI 5

Table 3.o.2-1 on Page E5-148 of Enclosure 5 to the letter dated April 21, 2017, shows that the confirmatory full load strainer test had a lower overall head loss after chemical precipitates were added (i.e., 11.12 ft - 3.5 ft = 7.6 ft) compared to the first full load test (i.e., 15.7 ft- 5.46 ft =10.2ft). For the earlier forming calcium phosphate precipitate, the confirmatory full load (i.e., 5.75 ft-3.5ft = 2.25 ft) head loss was about twice the value used in the VEGP chemical effects approach described on page E5-82. The NRC staff has observed significant differences in head loss tests when similar conditions were tested.

Please explain if using the results from the confirmatory full load strainer test (i.e., greater calcium phosphate head loss earlier, but less total head loss) results in greater risk (i.e., greater core damage frequency). If so, please provide the rationale for not using the confirmatory test results.

SNC Response to RAI 5

In the full load test, the head loss following the addition of the conventional debris was 5.46 ft, which increased to 6.57 ft after the calcium phosphate was added (1.11 ft increase), as shown in Table 3.o.2-1 of Enclosure 5 of the VEGP submittal (Reference 1 pp. E5-148). In the confirmatory test, the head loss following the addition of the conventional debris was only 3.50 ft, which increased to 5.75 ft after the calcium phosphate was added (2.25 ft increase), as shown in Table 3.o.2-1 of Enclosure 5 (Reference 1 pp. E5-148). Although the increase in head loss associated with calcium phosphate was higher in the confirmatory test, the overall head loss after all conventional and calcium phosphate debris was added was lower in the confirmatory test than the full load test. Therefore, use of the full load test is conservative for both the short-term head loss (with conventional debris and calcium phosphate) as well as the long-term head loss (with conventional debris, calcium phosphate, and SAS).

Note that potential variability in strainer head loss was evaluated as a sensitivity case as shown in Table 3-11 and Table 3-12 of Enclosure 3 (Reference 1 pp. E3-63 to E3-64). For this sensitivity case, the maximum incremental conventional debris head loss (from the full load test) was increased by 25% from 5.46 ft to 6.83 ft, the maximum incremental calcium phosphate head loss of 2.25 ft was used from the confirmatory test, and the maximum incremental SAS head loss (from the full load test) was increased by 25% from 5.24 ft to 6.55 ft. Although the head loss values for this sensitivity case significantly exceed the measured values from both the full load and confirmatory tests, the impact on ΔCDF is essentially negligible as shown in Table 3-12 of Enclosure 3 (slight increase in ΔCDF from 2.47E-08 to 2.60E-08 yr-1) (Reference 1, p. E3-64).

NRC RAI 6

Page E5-155 of Enclosure 5 to the letter dated April 21, 2017, states that the trisodium phosphate (TSP) "clock" for phosphate inhibition of aluminum surfaces starts when the pH rises above 6.84.

a. Please explain any differences between the projected dissolved post-loss-of-coolant accident (LOCA) pool TSP concentration at a 6.84 pH to the TSP concentration in the University of New Mexico (UNM) bench experiments.

b. Please clarify which Kerry J. Howe et al. paper bench test data at pH 6.84 was used to develop the aluminum release model (i.e., 6.5 mM, 10mM TSP).

SNC Response to RAI 6

The VEGP pH calculation does not calculate a time dependent pH profile, but the containment sump pool would, in reality, pass through a pH of 6.84 briefly as TSP dissolves. The final sump TSP concentration in the VEGP containment sump pool is 4.16 mM – 9.08 mM for a final pH range of 7.12 – 7.78, respectively. As described in Section 3.o.2.3 of Enclosure 5 of the VEGP submittal, for the purpose of determining the aluminum release rate, VEGP conservatively assumes that TSP instantaneously dissolves in the sump pool resulting in a maximum pH of 7.8 for the 30-day post-LOCA event (Reference 1 pp. E5-148 to E5-150). The injection sprays are unbuffered at a pH of 5.72. Therefore, the discussion of the TSP "clock" applies to the abrupt transition of the containment spray from injection from the RWST (pH 5.72) to recirculation from the containment sump pool (pH 7.8). For sprayed aluminum metal, the variable "t_{TSP}" (Equation 3.o.2.9-3 of Enclosure 5 (Reference 1 pp. E5-155)) is zero until the containment sprays switch

to recirculation, after which, it is the time since the start of recirculation. Therefore, the appropriate comparison is between the VEGP final containment sump pool TSP concentration of 9.08 mM at a pH of 7.78 and the Howe et al. paper bench test TSP concentrations.

The Howe et al. paper bench test data at pH 6.84 and a TSP concentration of 10 mM TSP were directly used to develop the aluminum release model. It should be clarified that the bench tests at pH 6.84 with 6.5 mM TSP also contained 10 mM of phosphate ions due to the addition of 3.5 mM of phosphoric acid, the conjugate acid of TSP. This test was run as a comparison with the 10 mM TSP test to determine the effect of Cl^- ions as described in Section 4.3 of the Howe et al. paper. This result indicated that the amount of chloride introduced in these tests with HCl was not sufficient to change the corrosion rate of aluminum in the presence of TSP.

Additionally, per Section 3.1 of the Howe et al. paper, "a test replicated the base immersion solution but with a lower TSP concentration (5.58 mM) and was found to have the same final aluminum concentration in solution as the 10 mM TSP solution."

Because the maximum final VEGP containment sump pool concentration of 9.08 mM is similar to the 10 mM concentration of the Howe et al. bench tests, and phosphate inhibition was shown to be insensitive to changes in phosphate concentrations between 5.58 mM and 10 mM, the Howe et al. equations are appropriate for use in the VEGP chemical effects analysis.

NRC RAI 7

The Kerry J. Howe et al. paper, "Corrosion and solubility in a TSP-buffered chemical environment following a loss of coolant accident: Part 1 - Aluminum," Nuclear Engineering and Design, Volume 292, October 2015: 296-305," is referenced in Enclosure 1 to the letter dated April 21, 2017. On Page E-24 it states it is only appropriate to use the phosphate passivation function within the range of experimental data. The VEGP submittal states that the phosphate passivation function is not assumed to extrapolate beyond the tested temperature range, but then seems to perform a defacto extrapolation by applying the same passivation function at the tested temperature boundaries to temperatures beyond the boundaries. The VEGP submittal justification is that the equation predicts faster passivation both above and below the temperature range. The NRC staff questions the validity of this approach since the stated conservatism is based on extrapolating the function beyond the test data. For example, the NRC staff questions if greater corrosion rates at the highest post-LOCA temperatures more than offsets the predicted faster time to passivation.

Please justify the use of the passivation function beyond the tested range.

SNC Response to RAI 7

As discussed in Section 3.o.2.9 of Enclosure 5 of the VEGP submittal, the passivation equation is constrained by temperature to avoid predicting faster passivation outside of the temperature range (Reference 1 pp. E5-156). The use of the passivation function with this temperature constraint is justified by modeling several integrated autoclave tests, as described in Section 3.o.2.9 of Enclosure 2 (Reference 1 pp. E2-157 to E2-163), and through the use of multiple conservatisms that bound the uncertainty in the model, as shown in the Response to RAI 8.

NRC RAI 8

The aluminum release from the Kerry J. Howe et al. paper prediction provides a reasonable fit to some of the Westinghouse's WCAP-17788-P, Revision 0, "Comprehensive Analysis and Test Program for GSI-191 Closure (PA-SEE-1090)" (ADAMS Accession No. ML 15210A667) autoclave test data with TSP buffer and similar pH values. In other cases, when considering the referenced autoclave tests (including additional tests where aluminum release data is available only after 24 hours) it appears the aluminum release is under predicted, by about a factor of 1.5 to 2, in three of seven TSP tests.

Please explain how the under prediction of aluminum release during some of the autoclave tests is being considered in the VEGP chemical effects methodology

SNC Response to RAI 8

Section 3.o.2.9 of Enclosure 2 of the VEGP submittal compared the aluminum concentration results of Autoclave Tests 39-01, IBOB 39-01, 40-01, 42-01, and 44-01 with predictions using the VEGP chemical effects methodology with the Howe et al. aluminum release equations (Reference 1 pp. E2-157 to E2-163). RAI 8 references additional autoclave tests where aluminum release data is only available after 24 hours. These tests are the out-of-bag retests IBOB 40-01 and IBOB 42-01. The aluminum concentration results for IBOB 40-01, IBOB 42-01, and IBOB 44-01 were determined using the precipitation boundary results in WCAP-17788. The following figures provide the results for these tests along with the results already provided in Section 3.o.2.9 of Enclosure 2 (Reference 1 pp. E2-157 to E2-163). [

]^{a,c}

a,c

Figure 8-1: In-Bag Test 39-01 and Out-of-Bag Test IBOB-39-01 (pH = 8.00) Aluminum Concentrations

a,c

Figure 8-2: In-Bag Test 40-01 and Out-of-Bag Test IBOB 40-01 (pH = 8.03) Aluminum Concentrations

a,c

Figure 8-3: In-Bag Test 42-01 and Out-of-Bag Test IBOB 42-01 (pH = 8.03) Aluminum Concentrations

a,c

Figure 8-4: In-Bag Test 44-01 and Out-of-Bag Test IBOB 44-01 (pH = 7.52) Aluminum Concentrations

In addition to the justification provided in Section 3.o.2.9 of Enclosure 2, both quantified and qualitative conservatisms may be used to further justify the use of the Howe et al. equations for aluminum release from aluminum metals, despite the under-predictions of Autoclave Tests 39-01, IBOB 39-01, and IBOB 42-01. The following list of conservatisms is provided:

1. The total test head loss is applied when precipitate is present at the strainers, and high NPSH and structural margins remain available (Reference 1, p. E5-103).
2. WCAP-16530-NP-A chemical surrogates were used in testing, which generate a significant head loss across a debris bed per the WCAP-16530-NP-A Safety Evaluation (Reference 1, p. E5-68).
3. By using the same equations as submerged aluminum, unsubmerged aluminum is treated as fully wetted, or submerged, in the containment spray solution.
4. As discussed in Section 3.o.2.9 of Enclosure 2, the autoclave tests demonstrate that little calcium would be released and calcium phosphate is unlikely to form and impact strainer head loss (Reference 1, p. E2-161).
5. No credit is taken for aluminum that remains soluble after precipitation occurs.
6. As further discussed in the Response to RAI 10, the aluminum solubility equation predicted precipitation to occur in the filtration samples of the modeled autoclave tests although no precipitation was observed.
7. The Vogtle double-ended pump suction LOCA with minimum safeguards temperature profiles are used to determine chemical release rates (Reference 1 pp. E5-149).
8. The maximum design basis recirculation pH of 7.8 is used to determine chemical release rates. A recirculation pH of 7.0, which is less than the design basis minimum of 7.12, is used for aluminum solubility. Different pH values for release and solubility were combined in a non-physical way, bounding the effects of all potential pH profile variations. (Reference 1 pp. E5-148 to E5-149).

The design basis maximum final containment sump pool pH was determined to be 7.78 by conservatively bounding laboratory titration results with an analytical model (7.8 is used in the final NARWHAL chemical analysis). The best estimate maximum final containment sump pool pH was determined to be 7.42 by using probabilistic estimates of the chemical concentrations in the containment sump pool for a Small Break LOCA and the chemical equilibrium software Visual MINTEQ 3.0. The Small Break LOCA value is considered a best estimate maximum value because the injected volumes of borated water are conservatively minimized. The best estimate Containment Sump Pool pH for a Large Break LOCA is 7.16 with maximized injected volumes of borated water. Additionally, as shown in the table below, this best estimate maximum pH qualitatively agrees with the measured pH in the Howe et al. bench tests as compared with the value calculated in the design basis calculation. Therefore, a best estimate maximum recirculation pH of 7.42 is acceptable for quantifying the conservatism of using the design basis maximum recirculation pH of 7.78.

Table 8-1: Comparison of Calculated and Measured pH Values

Source	pH	TSP	Boric Acid	Other
Design Basis Calculation	7.78	9.08 mM	194 mM	0.1527 mM LiOH
Howe et al.	7.84	10 mM	220 mM	15.4 mM NaOH
Howe et al.	7.34	10 mM	220 mM	N/A

Spreadsheet calculations, using the same chemical release methodology as was used in NARWHAL, were prepared to determine the bounding maximum amount of chemical precipitate for Vogtle using recirculation pH values of 7.78 and 7.42. The use of the design basis maximum pH of 7.78 for the Containment Sump Pool and the Containment Sprays (after the switchover to recirculation) conservatively overestimates the release of aluminum from aluminum metals by 230% versus the use of the best estimate maximum pH of 7.42 at the Vogtle minimum safeguards temperature profile.

If applied to the modeled autoclave test results discussed above, a 230% increase in the aluminum release rate from aluminum metals over that predicted by the Howe et al. equations would bound all data with the exception of the measured value of Test 39-01 at 480 minutes (see Figures 8-1, 8-2, 8-3, and 8-4). This value is considered an outlier since it falls outside of the trend of both in-bag Test 39-01 and out-of-bag Test IBOB 39-01, and no precipitation was detected after the apparent decrease in the measured concentration from 480 minutes to 1440 minutes. Therefore, the conservatism inherent in the use of a pH of 7.8 bounds the uncertainty in the use of the Howe et al. equations outside of the original range of pH values and temperatures. Figures 8-5 and 8-6 show the effect of a 230% increase in the aluminum release rate for the under-predicted Test 39-01, Test IBOB 39-01, and Test IBOB 42-01.

[ ]a,c

Figure 8-5: In-Bag Test 39-01 and Out-of-Bag Test IBOB-39-01 (pH = 8.00) Aluminum Concentrations with a 230% Multiplier

[ ]a,c

Figure 8-6: In-Bag Test 42-01 and Out-of-Bag Test IBOB 42-01 (pH = 8.03) Aluminum Concentrations with a 230% Multiplier

Several additional sensitivity cases have been run using the VEGP NARWHAL model to quantify the conservatisms in the base case. The ΔCDF of each of these cases as compared with the base model is presented in Table 8-2. Note that the ΔCDF values were calculated using the simplified risk estimation methodology outlined in Section 14.2 of Enclosure 3 (Reference 1 pp. E3-59 to E3-61).

Table 8-2: Additional Chemical Sensitivity Cases

Case	ΔCDF
Base VEGP NARWHAL Case	2.47E-08
Case 1: Conservative Models at Best Estimate Conditions	1.43E-08
Case 2: No Calcium Phosphate Debris Limit Failures	8.87E-09
Case 3: Conservative Models with Aluminum Solubility Credited	2.49E-08

In Case 1, the base VEGP NARWHAL model was modified with a combination of conservative chemical models and best estimate conditions. The following four changes were made:

1. The WCAP-16530-NP-A aluminum release from aluminum metal equation was conservatively used in place of the Howe et al. aluminum release equation. Therefore, phosphate passivation of aluminum is not credited in this case.
2. The Howe et al. aluminum solubility equation was conservatively used in place of the aluminum solubility model developed by Argonne National Laboratory. Therefore, aluminum is calculated to precipitate at higher temperatures and lower concentrations in this case.
3. The best estimate maximum pH (7.42) was used for the containment sump pool and the containment sprays (after the switchover to recirculation). The pH used for aluminum solubility was conservatively unchanged at 7.0.
4. The best estimate containment and sump temperature profiles for a double ended guillotine break of the hot leg developed by Texas A&M University was used. The best estimate containment and sump temperature profiles are compared with the design basis temperature profiles used in the base case in Figures 8-7 and 8-8. Note that the Texas A&M University temperature profiles were only calculated to 620 minutes post-LOCA, and the design basis temperature profiles were used for the remainder of the Case 1 temperature profiles.

The ΔCDF was reduced from 2.47E-08 to 1.43E-08 by this combination of the conservative chemical models and best estimate conditions.

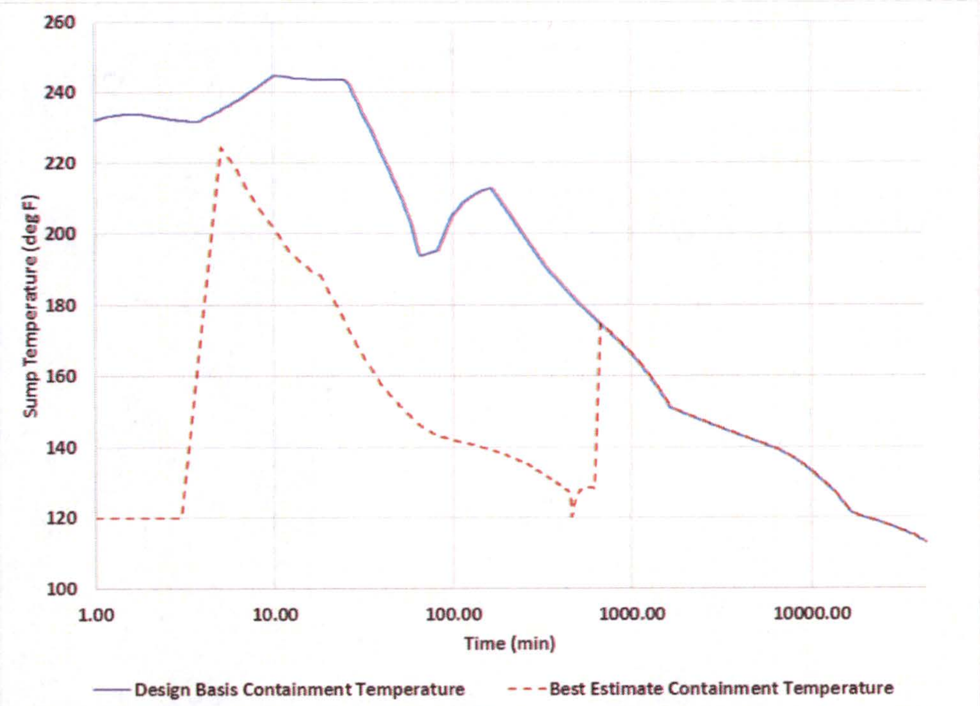

Figure 8-7: Best Estimate and Design Basis Containment Temperature Profiles

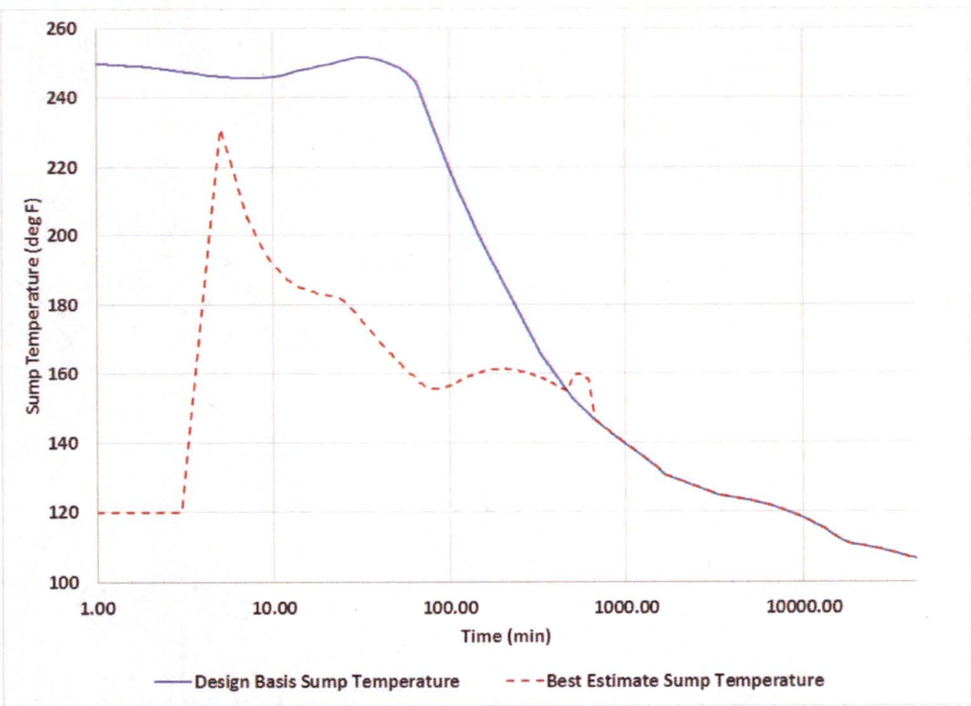

Figure 8-8: Best Estimate and Design Basis Sump Temperature Profiles

In Case 2, the base VEGP NARWHAL model was modified by increasing the calcium phosphate debris limit by a factor of 2.5. [

]^{a,c} To quantify the effects of this over-prediction, Case 2 was set up to effectively eliminate calcium phosphate debris limit failures. Note that full test head loss due to calcium phosphate was still added to the total head loss if calcium phosphate is present at an RHR strainer. The ΔCDF was reduced from 2.47E-08 to 8.87E-09 (a 64% reduction) by the elimination of calcium phosphate debris limit failures. This demonstrates that conservatisms resulting from the over-prediction of calcium phosphate contribute significantly to the calculated ΔCDF.

In Case 3, the base VEGP NARWHAL model was modified by using the WCAP-16530-NP-A aluminum release from aluminum metal equation (no phosphate passivation credited), using the Howe et al. aluminum solubility equation (predicts precipitation at higher temperatures and lower concentrations), and crediting residual solubility of aluminum after precipitation occurs up to the predicted solubility limit (some aluminum remains in solution). Note that aluminum precipitation was not forced at 24 hours for this sensitivity case. The ΔCDF increased slightly from 2.47E-08 to 2.49E-08 by this combination of the conservative chemical models and credit for the residual solubility of aluminum.

In conclusion, the under-prediction of aluminum release during some of the autoclave tests is being considered in the VEGP chemical effects methodology through the use of both qualitative and quantified conservatisms. The conservatism inherent in the use of a pH of 7.8 for the containment sump pool and the containment sprays (after the switchover to recirculation) bounds the uncertainty in the use of the Howe et al. equations outside of the original range of pH values and temperatures. Sensitivity cases using conservative chemical models show a decreased or only slightly increased ΔCDF when realistic aluminum solubility is assumed or best estimate conditions are used. Lastly, conservatisms resulting from the over-prediction of calcium phosphate contribute significantly to the calculated ΔCDF.

NRC RAI 9

Page E5-163 of Enclosure 5 to the letter dated April 21, 2017, states that the Kerry J. Howe et al. equations do not credit zinc inhibition of aluminum corrosion and that bench tests with zinc coupons present indicated aluminum corrosion can be reduced by approximately two-thirds.

a. The VEGP submittal relies on the equation for aluminium release described in Kerry J. Howe et al. paper. Please explain if the equation for aluminum release is expected to bound all the WCAP-17788-P autoclave TSP tests that included zinc coupons since it does not credit reduced aluminum corrosion due to zinc.
b. The VEGP supplement, dated July 11,2017, states that the aluminum release equation accurately predicts aluminum concentrations at higher pH when VEGP plant-specific or greater zinc quantities are present. Please describe how the VEGP plant-specific zinc quantity compare to that in Autoclave Test 42-01.
c. The Autoclave Test 42-01 appeared to have a 24-hour data point significantly above the predicted aluminum value. Please describe how the VEGP post LOCA zinc concentration varies with break size and location.

SNC Response to RAI 9a

The aluminum release equation is expected to bound aluminum release when zinc is present for conditions within the Howe et al. bench test range of pH values (6.84 – 7.84) and temperatures (131°F to 185°F). As described in Section 3.o.2.9 of Enclosure 2 of the VEGP submittal, autoclave tests were used to expand the applicable range of temperatures and pH values (Reference 1 pp. E2-156 to E2-163). [

]a,c The reduction in aluminum release was not 2/3 as in the bench tests. However, the effects of varying temperatures, pH, and zinc surface areas were not investigated by the bench tests.

SNC Response to RAI 9b

The plant-scale quantity of galvanized steel in each of the autoclave tests was conservatively determined (maximized) by multiplying the tested surface area by the ratio of the maximum containment sump pool volume to the test volume. [

]a,c

As of October 2017, the total galvanized steel surface area in the Vogtle containments exposed to the containment sump pool or containment spray fluid was 210,713 ft^2 for Unit 1 and 211,058 ft^2 for Unit 2, which is well in excess of the tested values. Additionally, the October 2017 quantity of zinc based paint was 684,803 ft^2 for Unit 1 and 685,136 ft^2 for Unit 2, although only destroyed/failed coatings would be in contact with the containment sump pool or containment spray fluid. The quantity of submerged vs. unsubmerged zinc is not determined, but zinc release is highest at acidic conditions that would be present during spray injection. Therefore, comparing the modeled results to the tested results is acceptable since zinc inhibition of aluminum release would be expected to be greater at Vogtle post-LOCA conditions than at the tested conditions.

SNC Response to RAI 9c

The post-LOCA zinc concentration is not modeled in the VEGP chemical effects methodology. Zinc release is expected to be higher at acidic pH values and lower temperatures. The galvanized steel surface area is not variable with break size and location. Depending on break size and location, destroyed zinc based paint could add to the quantity of exposed zinc. Larger surface areas of exposed zinc would be expected to further suppress aluminum release.

NRC RAI 10

As described in Enclosure 5 of the letter dated April 21, 2017 (Page E5-153), the VEGP chemical effects approach uses the aluminum solubility equation developed from work with alkaline solutions in borated water at the Argonne National Laboratory. The Kerry J. Howe et al. paper evaluated aluminum solubility in TSP buffered solutions and noted that the MINTEQ saturation line for Al(OH)3 line needed to be shifted by +.66 log units to fit the Chemical Head Loss Experiment tank tests data.

Please describe how the use of the Kerry J. Howe et al. paper recommended aluminum saturation (MINTEQ +.66 log units) change the VEGP chemical effects evaluation.

SNC Response to RAI 10

Using the VEGP chemical effects approach described in Section 3.o of Enclosure 5 of the VEGP submittal, the bounding maximum temperature at which aluminum precipitation could occur was determined to be 136.8°F. Using the Howe et al. aluminum saturation equation (MINTEQ + 0.66 log units) instead of the equation developed by Argonne National Laboratory would change the maximum bounding aluminum precipitation temperature to approximately 159°F. The strainer head loss limit is constant in this temperature range (i.e., the structural margin is limiting) (Reference 1 pp. E5-73 and E5-103), and no additional failures related to strainer head loss would occur. It should also be noted that the precipitate quantity would be unchanged, and the number of breaks that go to failure may be decreased if precipitation occurs earlier while debris can transport to the containment spray strainers.

The Howe et al. aluminum saturation equation (MINTEQ + 0.66 log units) was not used since integrated autoclave testing using TSP has shown that the equation developed by Argonne National Laboratory is conservative within the initial 24 hours following the LOCA. The Howe et al. aluminum saturation equation (MINTEQ + 0.66 log units) was designed to conservatively bound the results of the chemical head loss experiment (CHLE) tank tests, wherein precipitation was observed well after the initial 24 hours. The ANL aluminum solubility equation was used with the predicted concentrations in Figures 8-1 through 8-4 to determine the aluminum precipitation temperatures shown in Figures 10-1 through 10-4 for Autoclave Tests 39-01, 40-01, 42-01, and 44-01.

- For in-bag and out-of-bag Tests 39-01 (Figure 10-1), the ANL aluminum solubility equation predicted precipitation for the filtration tests performed at 480 and 1,440 minutes when no precipitation was observed in testing.
- For in-bag and out-of-bag Tests 40-01 (Figure 10-2), the ANL aluminum solubility equation predicted precipitation for the filtration tests performed at 240, 360, 480, and 1,440 minutes when no precipitation was observed in testing.
- For in-bag and out-of-bag Tests 42-01 (Figure 10-3), the ANL aluminum solubility equation predicted precipitation for the filtration tests performed at 480 and 1,440 minutes when no precipitation was observed in testing.
- For in-bag and out-of-bag Tests 44-01 (Figure 10-4), the ANL aluminum solubility equation predicted precipitation for the filtration tests performed at 120, 240, 360, 480, and 1,440 minutes when no precipitation was observed in testing.
- Precipitation was also predicted to occur within the autoclaves for Tests 40-01 (Figure 10-2) and 44-01 (Figure 10-4) when no precipitation was observed in testing.

Therefore, the aluminum solubility equation developed by Argonne National Laboratory and used in the Vogtle analysis is shown to conservatively predict precipitation over the initial 24 hours.

[ ]a,c

Figure 10-1: Autoclave Test 39-01 ANL Predicted Aluminum Precipitation Temperature

[ ]a,c

Figure 10-2: Autoclave Test 40-01 ANL Predicted Aluminum Precipitation Temperature

[ ]a,c

Figure 10-3: Autoclave Test 42-01 ANL Predicted Aluminum Precipitation Temperature

[ ]a,c

Figure 10-4: Autoclave Test 44-01 ANL Predicted Aluminum Precipitation Temperature

References

1. **ML17116A098.** NL-16-2002, Vogtle Electric Generating Plant - Units 1 & 2 Supplemental Response to NRC Generic Letter 2004-02. April 21, 2017.