B. H. Whitley
Director
Regulatory Affairs

Southern Nuclear
Operating Company, Inc.
42 Inverness Center Parkway
Birmingham, AL 35242

SOUTHERN COMPANY

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52-026

ND-13-2287
10 CFR 50.90

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555-0001

Southern Nuclear Operating Company
Vogtle Electric Generating Plant Units 3 and 4
Request for License Amendment:
Coating Thermal Conductivity (LAR-13-039)

Ladies and Gentlemen:

In accordance with 10 CFR 50.90, Southern Nuclear Operating Company (SNC), the licensee for Vogtle Electric Generating Plant (VEGP) Units 3 and 4, requests an amendment to Combined License (COL) Numbers NPF-91 and NPF-92, for VEGP Units 3 and 4, respectively.

This amendment request proposes to depart from approved AP1000 Design Control Document (DCD) Tier 2 information as incorporated into the Updated Final Safety Analysis Report (UFSAR) to allow use of a new methodology to determine the effective thermal conductivity resulting from oxidation of the inorganic zinc (IOZ) used in the containment vessel coating system. The proposed change would revise the licensing basis documents.

The description, technical evaluation, regulatory evaluation (including the Significant Hazards Consideration determination), and environmental considerations for the proposed changes in the License Amendment Request (LAR) are contained in Enclosure 1 to this letter. Enclosure 2 provides markups depicting the requested changes to the licensing basis documents. Enclosures 3 and 4 provide the bases for the withholding of proprietary information. Enclosure 5 is a non-proprietary copy of WCAP-15846-NP, Addendum 1, "Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000," Revision 0, October 2013, with redaction of the proprietary material included in Enclosure 6. Enclosure 6 provides the Proprietary version of the document. It is identified as WCAP-15846-P, Addendum 1, "Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000," Revision 0, October 2013.

As discussed above, Enclosure 6 contains proprietary information that Westinghouse and SNC request to be withheld from public disclosure under 10 CFR 2.390. Enclosures 3 and 4 support this request and are affidavits signed by appropriate representatives of Westinghouse and SNC. The affidavits set forth the bases upon which the information may be withheld from public disclosure by the Commission and address the considerations in 10 CFR 2.390(b)(4).

Correspondence with respect to the copyright or proprietary aspects of the items listed above or the supporting affidavits should reference CAW-13-3833 and should be addressed to J.A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, Suite 428, 1000 Westinghouse Drive, Cranberry Township, PA 16066, and also to Brian H. Whitley, SNC, at the contact information within this letter.

SNC's need date for approval of this license amendment is January 13, 2014. This date is based upon the scheduled construction activity for setting of the first ring of the lower containment vessel. SNC recognizes that January 2014 is a short time frame for approval of this license amendment and anticipates that it will submit a Preliminary Amendment Request (PAR) to support construction activities. In the event the NRC issues a "no objections" finding related to this license amendment, then the need date for the license amendment, i.e., the point at which SNC would not risk further construction under the "no objections" finding, is currently identified as March 2015.

SNC expects to implement the proposed amendment (through incorporation into the licensing basis documents, e.g., the UFSAR) within 30 days of approval of the requested change.

This letter contains no regulatory commitments.

In accordance with 10 CFR 50.91, SNC is notifying the State of Georgia of this LAR by transmitting a copy of this letter and enclosures to the designated State Official.

Should you have any questions, please contact Mr. Brian Meadors at (205) 992-7331.

Mr. Brian H. Whitley states that he is the Regulatory Affairs Director of Southern Nuclear Operating Company, is authorized to execute this oath on behalf of Southern Nuclear Operating Company and to the best of his knowledge and belief, the facts set forth in this letter are true.

Respectfully submitted,

SOUTHERN NUCLEAR OPERATING COMPANY

Brian H. Whitley

BHW/ERG/kms

Sworn to and subscribed before me this 21st day of November, 2013

Notary Public: Kristin Marie Seibert

My commission expires: August 16, 2016

KRISTIN MARIE SEIBERT NOTARY PUBLIC ALABAMA STATE AT LARGE

Enclosures:
1) Request for License Amendment, Coating Thermal Conductivity (LAR-13-039)
2) Proposed Changes to the Licensing Basis Documents (LAR-13-039)
3) Westinghouse Authorization Letter, Affidavit, Proprietary Information Notice and Copyright Notice
4) SNC Affidavit
5) WCAP-15846-NP, Addendum 1, Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000, Revision 0, October 2013 (Update to WCAP-15862 Section 10.2.1) (Non-Proprietary)
6) WCAP-15846-P, Addendum 1, Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000, Revision 0, October 2013 (Update to WCAP-15846 Section 10.2.1) (**Proprietary**)

cc:
<u>Southern Nuclear Operating Company/ Georgia Power Company</u>
Mr. S. E. Kuczynski (w/o enclosures)
Mr. J. A. Miller
Mr. D. A. Bost (w/o enclosures)
Mr. B. L. Ivey
Mr. M. D. Rauckhorst (w/o enclosures)
Mr. J. T. Gasser (w/o enclosures)
Mr. D. H. Jones (w/o enclosures)
Mr. J. R. Johnson (w/o enclosures)
Mr. T. E. Tynan (w/o enclosure 6)
Mr. D. M. Lloyd
Mr. B.H. Whitley
Mr. C. R. Pierce
Mr. D. L. Fulton
Mr. C. H. Mahan
Mr. S. Thomason
Ms. A. G. Aughtman
Mr. M. C. Medlock
Mr. W. A. Sparkman
Mr. C. B. Meadors
Document Services RTYPE: VND.RA.L06
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<u>Nuclear Regulatory Commission</u>
Mr. V. M. McCree (w/o enclosures)
Mr. F. M. Akstulewicz (w/o enclosures)
Mr. L. Burkhart (w/o enclosures)
Mr. D. H. Jaffe
Mr. R. G. Joshi
Ms. D. L. McGovern
Mr. B. M. Bavol
Ms. M. A. Sutton
Mr. M. E. Ernstes
Mr. G. Khouri
Mr. L. M. Cain
Mr. J. D. Fuller
Mr. C. B. Abbott
Mr. C. Huffman
Mr. A. J. Minarik

<u>State of Georgia</u>
Mr. J. H. Turner(w/o enclosure 6)

<u>Oglethorpe Power Corporation</u>
Mr. M. W. Price (w/o enclosure 6)
Mr. K. T. Haynes (w/o enclosure 6)

<u>Municipal Electric Authority of Georgia</u>
Mr. J. E. Fuller (w/o enclosure 6)
Mr. S. M. Jackson (w/o enclosure 6)

<u>Dalton Utilities</u>
Mr. D. Cope (w/o enclosure 6)

<u>CB&I</u>
Mr. J. Simmons (w/o enclosures)
Mr. G. Grant (w/o enclosures)
Ms. K. Stoner (w/o enclosures)
Mr. C. A. Castell

<u>Westinghouse Electric Company, LLC</u>
Mr. T. C. Geer (w/o enclosures)
Mr. S. W. Gray (w/o enclosures)
Mr. F. G. Gill
Mr. P. A. Russ
Mr. G. F. Couture
Mr. M. Y. Shaqqo

<u>Other</u>
Mr. R. W. Prunty, Bechtel Power Corporation
Ms. K. K. Patterson, Tetra Tech NUS, Inc. (w/o enclosure 6)
Dr. W. R. Jacobs, Jr., Ph.D., GDS Associates, Inc.
Mr. S. Roetger, Georgia Public Service Commission
Ms. S. W. Kernizan, Georgia Public Service Commission
Mr. K. C. Greene, Troutman Sanders
Mr. S. Blanton, Balch Bingham
Ms. A. Rice, South Carolina Electric & Gas Company
Mr. D. Kersey, South Carolina Electric & Gas Company
Mr. B. Kitchen, Duke Energy
Mr. S. Franzone, Florida Power & Light

Southern Nuclear Operating Company

Vogtle Electric Generating Plant Units 3 and 4

ND-13-2287

Enclosure 1

Request for License Amendment

Coating Thermal Conductivity

(LAR-13-039)

Table of Contents

In accordance with 10 CFR 50.90, Southern Nuclear Operating Company (SNC), the licensee for Vogtle Electric Generating Plant (VEGP) Units 3 and 4, requests an amendment to Combined License (COL) Numbers NPF-91 and NPF-92, for VEGP Units 3 and 4, respectively.

1. Summary Description

WCAP-15846, "WGOTHIC Application to AP600 and AP1000," describes specific modeling and defines methods used to develop conservative input for the WGOTHIC code to create a bounding containment peak pressure evaluation model (Updated Final Safety Analysis Report (UFSAR) Section 6.2, Reference 20). This containment evaluation model is used to calculate the design basis peak pressure reported in the UFSAR. WCAP-15846 provides the thermal conductivity value of the inorganic zinc (IOZ) coating to use for application to the AP1000® plant in support of containment response analyses. To conservatively account for the oxidation of the zinc constituent of the IOZ coating system, the methodology contained in WCAP-15846 stipulates that the overall thermal conductivity of the coating system is reduced by a factor of four to conservatively account for the effects of oxidation. This is a conservative but non-mechanistic assumption.

This proposed change would revise the COLs to allow use of a new methodology (found in WCAP-15846 Addendum 1) for determining the effective thermal conductivity of the IOZ coating system. This new methodology eliminates non-mechanistic modeling of IOZ thermal conductivity and accounts for a commercially available coating. The new methodology results in a thermal conductivity value greater than the thermal conductivity value used in the design and licensing basis analysis. Since a higher thermal conductivity value is better for heat transfer, the values used in the design and licensing basis analysis continue to be conservative and bounding. Therefore, the thermal conductivity value used in the design and licensing basis analysis is not changed and there is no change to the calculated design basis peak pressure reported in the UFSAR. The coating utilized for this project meets the criteria identified in the WCAP addendum for its use. This enclosure requests approval of the license amendment necessary to implement this change and its associated UFSAR changes.

2. Detailed Description

The containment vessel is a free standing cylindrical steel vessel with ellipsoidal upper and lower heads. The function of the containment vessel, as part of the overall containment system, is to contain the release of radioactivity following postulated design basis accidents. The containment vessel also functions as the safety-related ultimate heat sink by transferring the heat associated with accident sources to the surrounding environment. (UFSAR Section 6.0) Inorganic zinc is the basic coating applied to the inside surface of the containment vessel. Below the operating deck, most of the inorganic zinc coating is top coated with epoxy where enhanced decontamination is desired. The epoxy top coat on the containment vessel extends above the operating deck. Carbon steel and structural modules within the containment are coated with self-priming high solids epoxy (SPHSE). (UFSAR Subsection 6.1.2.1.2)

The exterior of the containment vessel is coated with the same inorganic zinc as is used inside of the containment vessel. Safety functions of the inorganic zinc above the operating deck for both inside and outside surfaces of the containment vessel as summarized in UFSAR Table 6.1-2, are to 1) promote wettability, 2) enhance heat conduction, 3) be nondetachable, and 4) inhibit corrosion. The specific safety function of interest in this departure is related to the coating's heat conduction properties.

The containment system is designed such that for break sizes up to and including the double-ended severance of a reactor coolant pipe or secondary side pipe, the containment peak pressure is below the design pressure. This capability is maintained by the containment system assuming the worst single failure affecting the operation of the passive containment cooling system (PCS).

UFSAR Subsection 6.2.1.1.3 identifies the Westinghouse-GOTHIC (WGOTHIC) computer code (Reference 20) as the computer program for modeling multiphase flow in the containment transient analysis. Reference 20 is WCAP-15846(P),"WGOTHIC Application to AP600 and AP1000," Revision 1, March 2004. The peak pressure analysis discussed in the section is dependent on the methodology identified in the WCAP. Included in that methodology is a determination of acceptability (conservatism) for the values utilized in the analysis. The methodology for determining adequate conservatism of one of those values is proposed to be revised. Specifically, the methodology for determining the change in thermal conductivity over time would be changed. Pursuant to 10 CFR Part 52, Appendix D, VIII.B.5(b)(8), prior NRC approval is required.

Table 6.2.1.1-8 of the UFSAR establishes a value of 0.302 Btu/hr-ft-°F as the thermal conductivity value of the inorganic zinc coating for application to the AP1000® plant in support of containment integrity analyses as presented in WCAP-15846(P),"WGOTHIC Application to AP600 and AP1000," Revision 1, March 2004. This value of thermal conductivity continues to be utilized in the containment peak pressure analysis. To conservatively account for the oxidation of the zinc constituent of the inorganic zinc coating system, the methodology identified in Section 10.2.1, Table 13-49, and Table 13-132 of WCAP-15846(P) stipulates the actual or overall thermal conductivity of the coating system is reduced by a factor of four, or 25% of its actual value, to determine the effective value in the containment analysis. This is a non-mechanistic reduction chosen to address degradation in thermal conductivity as the result of zinc oxidation; however, this factor of four reduction utilized to show conservatism has no technical basis. This assumption is predicated on the overall coating system thermal conductivity varying directly proportional to the performance of the zinc constituent. This is a conservative but non- mechanistic assumption because the coating system thermal performance is dictated by the total constituents of the coating system, and not solely by the performance of the zinc. Imposing a factor of four reduction of the thermal conductivity results in an overly conservative and non-technical reduction in the containment peak pressurization margin.

Implementation of a methodology that specifies a thermal conductivity value and oxidation progression over the plant lifetime based on coating system constituents is a new method of evaluation for showing the conservatism which eliminates the non-mechanistic modeling of inorganic zinc thermal conductivity in the containment peak pressure analyses. The IOZ thermal conductivity value specified in UFSAR Table 6.2.1.1-8 continues to be used in the containment integrity analyses and continues to be shown as bounding and conservative. Therefore, this methodology has no impact on the calculated containment peak pressure and no change to the current analysis of record is needed.

The new methodology is contained in WCAP-15846-P, Addendum 1, "Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000," Revision 0, October

2013 which presents an effective thermal conductivity model for use in determining the thermal conductivity of the inorganic zinc coating system and assesses/quantifies degradation effects for the effect on thermal performance of the inorganic zinc coating over the lifetime of the power plant. The model uses a multi-stage approach to effectively model the oxidation of the inorganic zinc coating system.

Licensing Basis Change Descriptions

The licensing basis changes sought with regard to implementation of a new methodology that can be used to determine effective thermal conductivity and oxidation progression over the life of the plant involve revising the COL Updated Final Safety Analysis Report (UFSAR) to add the WCAP-15846-P, Addendum 1, as a new reference and to add a general discussion of the use of the methodology in WCAP-15846-P, Addendum 1, as a means of addressing the IOZ thermal conductivity parameter used in the containment peak pressure evaluation.

The affected UFSAR Tier 2 material is proposed to be modified as discussed below and shown in Enclosure 2.

a) UFSAR Tier 2, Section 1.6, Table 1.6-1, Material Referenced, is revised to add the Addendum as referenced material for Section 6.2.
b) UFSAR Tier 2, Subsection 6.2.1.1.3, is modified at the end of the 9th paragraph to include appropriate text references for the new Addendum.
c) UFSAR Tier 2, Subsection 6.2.7, References, is revised to add the Addendum as new item 37.

3. Technical Evaluation

The Westinghouse-GOTHIC (WGOTHIC) computer code, WCAP-15846(P), is a computer program for modeling multiphase flow in a containment transient analysis. It solves the conservation equations in integral form for mass, energy, and momentum for multicomponent flow. The momentum conservation equations are written separately for each phase in the flow field (drops, liquid pools, and atmosphere vapor). The following terms are included in the momentum equation: storage, convection, surface stress, body force, boundary source, phase interface source, and equipment source. (UFSAR Subsection 6.2.1.1.3)

The passive internal containment heat sink data used in the WGOTHIC analyses is presented in WCAP-15846(P) (UFSAR Section 6.2, Reference 20), Section 13 and updated in APP-GW-GLR-096 UFSAR Section 6.2, Reference 36), "Evaluation of the Effect of AP1000 Enhanced Shield Building Design on the Containment Response and Safety Analysis," Rev. 3, June 2011. Data for both metallic and concrete heat sinks are presented. Additional heat sink data utilized in the containment peak pressure analysis, as updated in APP-GW-GLR-096, Rev 3, are identified in UFSAR Table 6.2.1.1-10. These additional heat sinks are characterized as metal gratings with material type and minimum required surface area and volume within the subcompartment defined in UFSAR Table 6.2.1.1-10. The physical properties of the materials corresponding to the heat sink information are presented in UFSAR Table 6.2.1.1-8.

The inorganic zinc coating on the outside of the containment shell above elevation 135'-3′ supports passive containment cooling system heat transfer and is classified as a Service

Level III coating. The inorganic zinc coating used on the inside surface of the containment shell above the operating deck, supports the transfer of thermal energy from the post-accident atmosphere inside containment to the containment shell. Passive containment cooling system testing and analysis have been performed with an inorganic zinc coating. As identified in UFSAR Table 6.1-2, this coating is classified as Service Level I coating.

Implementation of the methodology presented in WCAP-15846(P) Addendum 1 specifies an effective thermal conductivity based on the distribution of the constituents in the inorganic zinc. Based on discussions with an inorganic zinc coating system vendor, a typical inorganic zinc coating system contains elemental zinc, binder, silicates and air as the major constituents.

Implementation of the methodology specifies an effective thermal conductivity by a multi-stage approach to effectively model the oxidation of the inorganic zinc coating system and demonstrates in WCAP 15846-P, Addendum 1, Section 3, that the current assumed value in the UFSAR Table 6.2.1.1-8 is conservative and has no impact on the calculated containment peak pressure, and thus, demonstrates the current analysis of record is bounding and does not need to be changed.

The change in methodology to determine an effective thermal conductivity and oxidation progression over the life of the plant for the inorganic zinc coating system used inside and outside containment to show the IOZ thermal conductivity value used in the containment integrity analyses is conservative does not affect the thermal conductivity value used in the containment peak pressure analyses as provided in UFSAR Table 6.2.1.1-8, and, therefore, does not affect the calculated peak containment pressure reported in the UFSAR. The proposed change does not affect a function or feature used for the prevention and mitigation of accidents or their safety analyses. The proposed change does not involve nor interface with any structure, system, and component accident initiator or initiating sequence of events related to the accidents evaluated in the UFSAR. The proposed change does not affect the radiological source terms (i.e., amounts and types of radioactive materials released, their release rates and release durations) used in the accident analyses.

Determining an effective thermal conductivity and oxidation progression for the life of the plant for the inorganic zinc coating system by a new methodology does not impact the thermal conductivity value used for inorganic zinc in the containment peak pressure analyses and as cited in UFSAR Table 6.2.1.1-8. No system or design function or equipment qualification is adversely affected by the proposed change. The change does not result in a new failure mode, malfunction or sequence of events that could adversely affect a radioactive material barrier or safety-related equipment. The proposed change does not allow for a new fission product release path, result in a new fission product barrier failure mode, or create a new sequence of events that would result in significant fuel cladding failures.

The new methodology for determining an effective thermal conductivity and oxidation progression over the life of the plant for the inorganic zinc coating system to show the IOZ thermal conductivity value used in the containment integrity analyses is conservative does not affect the performance of the primary containment to provide a boundary function during operation and following an accident. The proposed change does not affect any safety-related equipment, design code limit allowable value, safety-related function or design analysis, nor does it affect any safety analysis input or result, or design/safety margin.

The proposed change does not affect the containment, control, channeling, monitoring, processing or releasing of radioactive and non-radioactive materials. No effluent release path is affected by the proposed change. Therefore, neither radioactive nor non-radioactive material effluents are affected by the proposed change.

Plant radiation zones (as described in UFSAR Section 12.3), radiation controls established to satisfy 10 CFR 20 requirements, and expected amounts and types of radioactive materials are not affected by the proposed change. Therefore, individual and cumulative radiation exposures are not affected by this change.

The proposed change does not affect any vital area boundaries or to any perimeter walls acting as a security barrier or other aspects of the structures that could affect physical security.

4. Regulatory Evaluation

4.1 Applicable Regulatory Requirements/Criteria

10 CFR 52, Appendix D, Section VIII.B.5.a allows an applicant or licensee who references this appendix to depart from Tier 2 information, without prior NRC approval, unless the proposed departure involves a change to or departure from Tier 1 information, Tier 2* information, or the Technical Specifications, or requires a license amendment under paragraphs B.5.b or B.5.c of the section. This change involves a departure from a method of evaluation, as cited in section B.5.b.(8), for the determination of effective thermal conductivity and oxidation progression over the life of the plant for the inorganic zinc coating system for the containment vessel and requires a license amendment.

10 CFR 50, Appendix A, General Design Criterion (GDC) 16—Containment design requires that the reactor containment and associated systems be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

The proposed change does not affect the leak tightness of the containment or impact its ability to withstand the design conditions. The new methodology for determining an effective thermal conductivity and oxidation progression does not impact the current thermal conductivity and degradation used in the current containment peak pressure analysis.

4.2 Precedent

No precedent is identified.

4.3 Significant Hazards Consideration Determination

The requested change would revise the licensing basis documents to include a new methodology for determining the effective thermal conductivity for the primary containment inorganic zinc coating. Reference to and general discussion of the use of the methodology in WCAP-15846, Addendum 1, “Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000," Revision 0, October 2013, is proposed to be included in Updated Final Safety Analysis Report (UFSAR) Section 1.6 Table 1.6-1, Subsection 6.2.1.1.3, and Subsection 6.2.7.

The requested amendment proposes changes to UFSAR Tier 2 information.

An evaluation to determine whether or not a significant hazards consideration is involved with the proposed amendment was completed by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of Amendment," as discussed below:

4.3.1 Does the proposed amendment involve a significant increase in the probability or consequences of an accident previously evaluated?

Response: No

Implementation of a methodology which specifies an effective thermal conductivity and oxidation progression for the inorganic zinc coating of the containment vessel is used to eliminate non-mechanistic modeling of inorganic zinc thermal conductivity in the containment integrity analyses to show that the value for inorganic zinc thermal conductivity used in the containment integrity analyses is conservative, but is not used to change any of the parameters used in those analyses. There is no change to any accident initiator or condition of the containment that would affect the probability of any accident. The containment peak pressure analysis as reported in the UFSAR is not affected; therefore, the previously reported consequences are not affected.

Therefore, the proposed amendment does not involve a significant increase in the probability or consequences of an accident previously evaluated.

4.3.2 Does the proposed amendment create the possibility of a new or different kind of accident from any accident previously evaluated?

Response: No

The proposed amendment to implement a methodology which specifies an effective thermal conductivity and oxidation progression and effects for the inorganic zinc coating of the containment vessel is used to eliminate non-mechanistic modeling of inorganic zinc thermal conductivity in the containment integrity analyses to show that the value for inorganic zinc thermal conductivity used in the containment integrity analyses is conservative, but is not used to change any of the parameters used in the containment peak pressure analysis. The change in methodology does not change the condition of containment; therefore, no new accident initiator is created. The containment peak pressure analysis as currently evaluated is not affected, and the consequences previously reported are not changed. The new methodology does not change the containment; therefore, no new fault or sequence of events that could lead to containment failure or release of radioactive material is created.

Therefore, the proposed amendment does not create the possibility of a new or different kind of accident from any accident previously evaluated.

4.3.3 Does the proposed amendment involve a significant reduction in a margin of safety?

Response: No

The proposed implementation of a methodology which specifies an effective thermal conductivity and oxidation progression and effects for the inorganic zinc coating of the containment vessel is used to eliminate non-mechanistic modeling of inorganic zinc thermal conductivity in the containment integrity analyses to show that the value for inorganic zinc thermal conductivity used in the containment integrity analyses is conservative, but is not used to change any of the parameters used in the containment peak pressure analysis. The change in methodology does not change the condition of the containment and the integrity of the containment vessel is not affected. The containment peak pressure analysis as currently evaluated is not affected, and the consequences previously reported are not changed. No safety analysis or design basis acceptance limit/criterion is changed by the proposed change, thus no margin of safety is reduced.

Therefore, the proposed amendment does not involve a significant reduction in a margin of safety.

Based on the above, it is concluded that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and, accordingly, a finding of “no significant hazards consideration” is justified.

4.4 Conclusions

Based on the considerations discussed above, (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission’s regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

5. Environmental Considerations

This review supports a request to amend the licensing basis documents to allow departure from the plant-specific Design Control Document (DCD) as incorporated into the Updated Final Safety Analysis Report (UFSAR) related to a new methodology used to determine effective thermal conductivity and oxidation progression for the inorganic zinc coating of the containment vessel.

The proposed change requires revisions to UFSAR information.

A review has determined that the proposed amendment would change a requirement with respect to installation or use of a facility component located within the restricted area, as defined in 10 CFR Part 20, or would change an inspection or surveillance requirement. However, facility construction and operation following implementation of the proposed amendment does not involve (i) a significant hazards consideration, (ii) a significant change in the types or a significant increase in the amounts of any effluents that may be released offsite, or (iii) a significant increase in individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9), in that:

(i) There is no significant hazards consideration.

As documented in Section 4.3, Significant Hazards Consideration Determination, of this license amendment request, an evaluation was completed to determine whether or not a significant hazards consideration is involved by focusing on the three standards set forth in 10 CFR 50.92, "Issuance of amendment." The Significant Hazards Consideration determined that (1) the proposed amendment does not involve a significant increase in the probability or consequences of an accident previously evaluated; (2) the proposed amendment does not create the possibility of a new or different kind of accident from any accident previously evaluated; and (3) the proposed amendment does not involve a significant reduction in a margin of safety. Therefore, it is concluded that the proposed amendment does not involve a significant hazards consideration under the standards set forth in 10 CFR 50.92(c), and accordingly, a finding of "no significant hazards consideration" is justified.

(ii) There is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite.

The proposed change is unrelated to any aspect of plant construction or operation that would introduce any change to effluent types (e.g., effluents containing chemicals or biocides, sanitary system effluents, and other effluents), or affect any plant radiological or non-radiological effluent release quantities. Furthermore, the proposed change does not affect any effluent release path or diminish the functionality of any design or operational features that are credited with controlling the release of effluents during plant operation. Therefore, it is concluded that the proposed amendment does not involve a significant change in the types or a significant increase in the amounts of any effluents that may be released offsite.

(iii) There is no significant increase in individual or cumulative occupational radiation exposure.

The proposed change provides an alternate methodology of determining the effective thermal conductivity and oxidation progression for the inorganic zinc coating of the containment vessel. Plant radiation zones (addressed in UFSAR Section 12.3) are not affected, and there are no changes to the controls required under 10 CFR Part 20 that preclude a significant increase in occupational radiation exposure. Therefore, the proposed amendment does not involve a significant increase in individual or cumulative occupational radiation exposure.

Based on the above review of the proposed amendment, it has been determined that anticipated construction and operational effects of the proposed amendment do not involve (i) a significant hazards consideration, (ii) a significant change in the types or significant increase in the amounts of any effluents that may be released offsite, or (iii) a significant increase in the individual or cumulative occupational radiation exposure. Accordingly, the proposed amendment meets the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Therefore, pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the proposed amendment.

Southern Nuclear Operating Company

Vogtle Electric Generating Plant Units 3 and 4

ND-13-2287

Enclosure 2

Proposed Changes to the Licensing Basis Documents

(LAR-13-039)

UFSAR Section 1.6, Table 1.6-1, Material Referenced - Revise to include the WCAP Addendum as referenced material as shown below.

DCD Section Number	Westinghouse Topical Report Number	Title
6.2	WCAP-15846(P) WCAP-15862	WGOTHIC Application to AP600 and AP1000, Revision 1, March 2004
	WCAP-15846-P Addendum 1 WCAP-15846-NP Addendum 1	Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000, Revision 0, October 2013

UFSAR Subsection 6.2.1.1.3, Design Evaluation - Revise the final sentence of the ninth paragraph as shown below:

The physical properties of the materials corresponding to the heat sink information used in the containment peak pressure evaluation (Reference 20 and updated in Reference 36) are presented in Table 6.2.1.1-8. These properties represent inputs to the containment peak pressure evaluation, and in some cases, reflect methodology specified in Reference 20. For inorganic zinc, the properties specified in Table 6.2.1.1-8, Reference 36, and Table 13-49 of Reference 20, are determined to be conservatively used as determined in Reference 37 and the associated reductions identified in subsection 10.2.1 and Table 13-132 of Reference 20 are not used for this input parameter. The conditions for use identified in Section 4 of Reference 37 are met.

UFSAR Subsection 6.2.7, References - Revise to include the WCAP Addendum as a new reference as shown below:

37. WCAP-15846-P (Proprietary), Addendum 1 and WCAP-15846-NP (Non-Proprietary) Addendum 1, “Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000,” Revision 0, October 2013.

New UFSAR Referenced WCAP material as shown in Enclosures 5 (Non-proprietary) and 6 (Proprietary).

Southern Nuclear Operating Company

Vogtle Electric Generating Plant Units 3 and 4

ND-13-2287

Enclosure 3

**Westinghouse Authorization Letter, Affidavit,
Proprietary Information Notice and Copyright Notice**

(LAR-13-039)

(This cover page and 7 additional pages.)

October 22, 2013

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

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Westinghouse

Westinghouse Electric Company
Nuclear Power Plants
1000 Westinghouse Drive
Cranberry Township, Pennsylvania 16066
USA

Document Control Desk
U S Nuclear Regulatory Commission
Washington, DC 20852-2738

Direct tel: 412-374-6206
Direct fax: 724-940-8505
e-mail: sisk1rb@westinghouse.com
Project letter: SVP_SV0_002147

Our ref: CAW-13-3833

October 22, 2013

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Transmittal of WCAP-15846-P & -NP Addendum 1, Revision 0, Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000

The proprietary information for which withholding is being requested in the above-referenced letter is further identified in the affidavit signed by Westinghouse Electric Company LLC. The affidavit accompanying this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and address 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.**

Correspondence with respect to the proprietary aspects of this application for withholding or the accompanying affidavit should reference CAW-13-3833 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, Suite 428, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066.

Very truly yours,

Robert B. Sisk
Program Manager APR1400 Licensing Support

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared **Robert B. Sisk**, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Robert B. Sisk
Program Manager APR1400 Licensing Support

Sworn to and subscribed
before me this 22nd day
of October 2013.

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Linda J. Bugle, Notary Public
City of Pittsburgh, Allegheny County
My Commission Expires June 18, 2017
MEMBER, PENNSYLVANIA ASSOCIATION OF NOTARIES

Notary Public

(1) I am Program Manager APR1400 Licensing Support, 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 Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" 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.

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.

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

(iv) 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.

(v) The proprietary information sought to be withheld from within the WCAP-15846-P Addendum 1, Revision 0, Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000, and may be used only for that purpose.

The information requested to be withheld reveals details of the AP1000 design; sequence and method of construction; and timing and content of inspection and testing. This information was developed and continues to be developed by Westinghouse. The information is part of that which enables Westinghouse to manufacture and deliver products to utilities based on proprietary designs.

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 commercial power reactors without commensurate expenses.

The information requested to be withheld 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.

Southern Nuclear Operating Company

Vogtle Electric Generating Plant Units 3 and 4

ND-13-2287

Enclosure 4

SNC Affidavit

(LAR-13-039)

(This cover page and 2 additional pages.)

Affidavit of Brian H. Whitley

1. My name is Brian H. Whitley. I am the Regulatory Affairs Director, Nuclear Development, for Southern Nuclear Operating Company (SNC). I have been delegated the function of reviewing proprietary information sought to be withheld from public disclosure and am authorized to apply for its withholding on behalf of SNC.
2. I am making this affidavit on personal knowledge, in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations, and in conjunction with SNC's filings and supplement on dockets 52-025 and 52-026, Vogtle Electric Generating Plant (VEGP) Units 3 and 4, Request for License Amendment, Coating Thermal Conductivity, (LAR-13-039). I have personal knowledge of the criteria and procedures used by SNC to designate information as a trade secret, privileged or as confidential commercial or financial information.
3. Based on the reason(s) at 10 CFR 2.390(a)(4), this affidavit seeks to withhold from public disclosure Enclosure 6 of Vogtle Electric Generating Plant (VEGP) Units 3 and 4, Request for License Amendment, Coating Thermal Conductivity, (LAR-13-039).
4. The following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.
    a. The information sought to be withheld from public disclosure has been held in confidence by SNC and Westinghouse Electric Company.
    b. The information is of a type customarily held in confidence by SNC and Westinghouse and not customarily disclosed to the public.
    c. The release of the information might result in the loss of an existing or potential competitive advantage to SNC and/or Westinghouse.
    d. Other reasons identified in Enclosure 3 of Vogtle Electric Generating Plant (VEGP) Units 3 and 4, Request for License Amendment, Coating Thermal

Conductivity, (LAR-13-039) (dockets 52-025 and 52-026), and those reasons are incorporated here by reference.

5. Additionally, release of the information may harm SNC because SNC has a contractual relationship with the Westinghouse Electric Company regarding proprietary information. SNC is contractually obligated to seek confidential and proprietary treatment of the information.
6. The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.
7. To the best of my knowledge and belief, 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.

I declare under penalty of perjury that the foregoing is true and correct.

Brian H. Whitley

Executed on 11/21/13
Date

Southern Nuclear Operating Company

Vogtle Electric Generating Plant Units 3 and 4

ND-13-2287

Enclosure 5

WCAP-15846-NP, Addendum 1,
Effective Thermal Conductivity Model of Inorganic Zinc Coating
for Application to AP1000,
Revision 0, October 2013
(Update to WCAP-15862, Section 10.2.1)
(Non-Proprietary)

(LAR-13-039)

WCAP-15846-NP Addendum 1
Revision 0

October 2013

Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000

Westinghouse

WESTINGHOUSE NON-PROPRIETARY CLASS 3

WCAP-15846-NP Addendum 1
Revision 0

Effective Thermal Conductivity Model of Inorganic Zinc Coating for Application to AP1000

T.A. Kindred*
AP1000 Special Projects Integration

October 2013

Reviewer: R.F. Wright*
Passive Plant Technology

Approved: K. Bonadio, Manager
Containment and Radiological Analysis

*Electronically approved records are authenticated in the electronic document management system.

Westinghouse Electric Company LLC
1000 Westinghouse Drive
Cranberry Township, PA 16066, USA

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1 PURPOSE

The purpose of this WCAP addendum is to develop an effective thermal conductivity (k_{eff}) model for use in determining the thermal conductivity of the inorganic zinc (IOZ) coating system, and to assess/quantify the degradation effects, if any, that could affect the thermal performance of the IOZ coating over the design lifetime of the AP1000® plant. The premise of the method is that if a higher value of thermal conductivity than that used in the current analysis is determined, then the heat transfer is better than that modeled in the current analysis, which is conservative.

This methodology will not be used to justify a higher value of thermal conductivity for the IOZ system, but rather will demonstrate that the current assumed value in the approved methodology and the AP1000 plant containment integrity analyses is conservative with respect to thermal conductivity degradation associated with oxidation of the coating system.

1.1 BACKGROUND

WCAP-15846/APP-SSAR-GSC-587 (Reference 1) provides the thermal conductivity value of the IOZ coating to use for application to the AP1000 plant in support of containment response analyses. To conservatively account for the oxidation of the IOZ constituent of the IOZ coating system, the methodology contained in subsection 10.2.1 of Reference 1 stipulates that the overall thermal conductivity of the coating system is reduced by a factor of 4 to conservatively account for the effects of oxidation. This assumption is predicated on the premise that the thermal conductivity of the overall coating system varies directly proportional to the performance of the zinc constituent. This is a conservative but non-mechanistic assumption, because the coating system thermal performance is dictated by the total constituents of the coating system, and not solely by the performance of the zinc. Upon investigation there appears to be no technical basis for the factor of 4 reduction in the coating thermal conductivity. The original method assumed there would be some sort of degradation in thermal conductivity associated with the oxidation of zinc, but a mechanistic method for determining the extent of that degradation was never presented.

1.1.1 IOZ System Constituents

The AP1000 plant Design Control Document (DCD) Table 6.2.1.1-8 specifies the value of IOZ thermal conductivity to use in the licensing basis containment integrity analyses as 0.302 Btu/hr-ft-°F. Based on discussions with an IOZ coating system vendor (Reference 2), a typical IOZ coating system contains the following bulk constituents by volume fraction:
[

]a,b,c

Approximately 2 percent volume fraction is represented by coloring agents like titanium oxide (TiO_2).

1.1.2 Model Background

There is a substantial amount of work available in the open literature regarding k_{eff} models of multiconstituent particle systems and complex porous media. Reference 3 provides a good review of widely accepted thermal conductivity models. These include but are not limited to:

- Parallel model
- Maxwell-Eucken 1
- Effective medium theory (EMT) model
- Maxwell-Eucken 2
- Series model

In addition to the above mentioned models, one of the most widely accepted empirical thermal conductivity models is that of Krischer (Reference 4). However, Krischer's model includes an empirical shape factor (Z) for which test data are required to implement.

1.1.3 Model Discussion

Parallel Model

Implementation of the parallel model will yield the highest value of k_{eff} because this model assumes the highest thermal conductivity constituents are in contact with each other, and thus the overall model thermal conductivity is dictated by the constituent with the highest thermal conductivity due to direct conduction of the high conductivity constituents. The formula for calculating k_{eff} from the parallel model is:

$$k_{parallel} = \sum_{i=1}^{I} n_i k_i \tag{1}$$

where:

$k_{parallel}$	=	the effective thermal conductivity calculated by the parallel model
i	=	subscript denoting i^{th} constituent
I	=	total number of constituents
n_i	=	volume fraction of i^{th} constituent
k_i	=	thermal conductivity of i^{th} constituent

Maxwell-Eucken 1 and 2

The Maxwell-Eucken models are discussed in Reference 3 and assume a dispersion of small spheres within a continuous matrix. Whether the high or low constituent forms the dispersed or continuous phase determines which Maxwell-Eucken model to implement. These models are not ideal for modeling the

IOZ system because they are limited to a two-constituent system. As identified in subsection 1.2.1, the IOZ system contains six constituent groups. Since the Maxwell-Eucken models are not easily expanded to more than two constituents, they cannot be used for determining the effective thermal conductivity of the IOZ system.

Effective Medium Theory

The EMT assumes that the constituent distribution is completely random and homogeneously dispersed within the particulate system, but that a loose coupling of individual constituents exists. This theory in principle is expandable from the Reference 3 model and is given by:

$$\sum_{i=1}^{I} n_i \frac{k_i - k_{EMT}}{k_i + 2k_{EMT}} = 0$$

where:

k_{EMT} = the effective thermal conductivity calculated by the EMT method
i = subscript denoting i^{th} constituent
I = total number of constituents
n_i = volume fraction of i^{th} constituent
k_i = thermal conductivity of i^{th} constituent

Once again, it is important to note that the EMT model assumes a loose thermal coupling of the individual constituents within the structure.

Harmonic Series

The harmonic series model assumes the particle constituents are settled in layers within the structure and that the heat flux must conduct through each layer independently. The k_{eff} calculated by the harmonic series model is dominated by the lowest thermal conductivity particulate constituent. The relation for the harmonic series model is:

$$k_{series} = \sum_{i=1}^{I} \frac{1}{n_i k_i}$$

where:

k_{series} = effective thermal conductivity calculated by the series model
n_i = volume fraction of i^{th} constituent
k_i = thermal conductivity of i^{th} constituent

Krischer Model

The Krischer model is an empirically developed model based on the combination of series and parallel models. The empirical component of the Krischer model specifies a weighting factor that relates the structure of the system to the combined parallel and series models. The drawback to the Krischer model is that empirical data for measured effective thermal conductivity is required for implementation. The equation for calculating the effective thermal conductivity from the Krischer model is:

$$k_{Krischer} = \frac{1}{Z(\sum_{i=1}^{I} \frac{n_i}{k_i}) + \frac{1-Z}{\sum_{i=1}^{I} n_i k_i}}$$

where:

$k_{Krischer}$ = calculated effective thermal conductivity from the Krischer model
n_i = volume fraction of i^{th} constituent
k_i = thermal conductivity of i^{th} constituent
Z = empirical weighting (distribution) factor

It is important to note that a Z value of 0 means that the Krischer model reduces to the parallel model, and conversely, a Z value of 1 means the Krischer model reduces to the harmonic series model. In the presence of empirical data for measured effective thermal conductivity, and provided the thermal conductivity and volume fraction of each constituent is known, it is possible to solve for the empirical weighting factor Z.

2 METHODOLOGY

2.1.1 Method Discussion

Subsection 1.1.2 displays and discusses various forms of effective thermal conductivity models that can be used to determine the effective thermal conductivity of a multiple-component material. Each method has drawbacks and advantages. The parallel, series, and EMT methods prescribe models that allow for direct calculation of k_{eff}, provided that the structure of the material is known and the appropriate model can be selected based on the structure of the material. The Krischer model allows for an empirical calculation of k_{eff} provided that test data speficying the value of k_{eff} exist. The advantage of the Krischer model is that the exact material structure need not be known.

The open literature contains numerous proposed k_{eff} models (References 5–8) where attempts are made to discern the shape or weighting factor that is analogous to determining how the individual constituents are arranged and how they contribute to the overall k_{eff} of the material. Some proposed models attempt to account for random distribution of particles, variations in size of particles, and even variations in shapes of particles. However, one thing is common among all proposed models, and that is for complex multi constituent materials, a distribution or weighting function relating the structure of the material is required to yield an accurate prediction of thermal conductivity. [

]^{a,c}

a,c

[ ]

Figure 2-1 [ ]^{a,c}

Carboline 11 HSN is/are trademarks or registered trademarks of their respective owner. Other names may be trademarks of their respective owners.

[

][a,b,c] This is due to the apparent random nature of the coating. A pure parallel or harmonic series is not applicable because the constituent structure is random and amorphous, or unrepeatable. The Maxwell-Eucken 1 and 2 models are not applicable because the coating structure contains at least five constituents, and the Maxwell-Eucken 1 and 2 models are only viable for a maximum of two constituents or phases.

2.1.2 Considerations

2.1.2.1 Model Applicability

Figure 2-2 (Reference 3) demonstrates graphically the physical representation of the models. The parallel and series models are well defined and applicable to rigid and repeatable structures. Figure 2-1 demonstrates that the coating structure, while rigid, is not repeatable. Figure 2-2 also shows the Maxwell-Eucken 1 and 2 models are only viable for two constituents or two-phase systems. The EMT method appears to physically represent both a random and amorphous structure, which could potentially be capable of adequately characterizing the coating structure. However, it is important to note Reference 4 indicates that there is a loose coupling of constituent phases from the EMT model. Figure 2-3 (Reference 4) shows the transport of the heat flux vectors (in red) associated with the EMT model. This indicates that while the high conductivity constituents are not in direct contact, there does exist a “loose coupling” between high conductivity constituents. Due to this phenomenon, the EMT will probably predict a higher than actual value of thermal conductivity, especially if the low conductivity constituents represent a large disparity (order of magnitude) between associated constituent conductivity values.

Table 1
Five fundamental effective thermal conductivity structural models for two-component materials (assuming the heat flow is in the vertical direction)

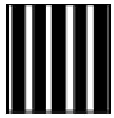
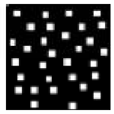
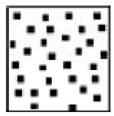
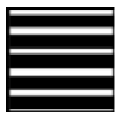
Model	Structure schematic	Effective thermal conductivity equation	Reference	Eq. (1) parameter values
Parallel model		$K = v_1k_1 + v_2k_2$		$d_i \to \infty$ or $\tilde{k} = k_i$
Maxwell–Eucken 1 (ME1) (k_1 = continuous phase, k_2 = dispersed phase)		$K = \dfrac{k_1v_1 + k_2v_2\frac{3k_1}{2k_1+k_2}}{v_1 + v_2\frac{3k_1}{2k_1+k_2}}$	[8,9]	$d_i = 3$ and $\tilde{k} = k_1$
EMT model		$v_1\dfrac{k_1 - K}{k_1 + 2K} + v_2\dfrac{k_2 - K}{k_2 + 2K} = 0$	[10,11]	$d_i = 3$ and $\tilde{k} = K$
Maxwell–Eucken 2 (ME2) (k_1 = dispersed phase, k_2 = continuous phase)		$K = \dfrac{k_2v_2 + k_1v_1\frac{3k_2}{2k_2+k_1}}{v_2 + v_1\frac{3k_2}{2k_2+k_1}}$	[8,9]	$d_i = 3$ and $\tilde{k} = k_2$
Series model		$K = \dfrac{1}{v_1/k_1 + v_2/k_2}$		$d_i = 1$ or $\tilde{k} \to 0$

Figure 2-2 Physical Interpretation of Accepted k_{eff} Models

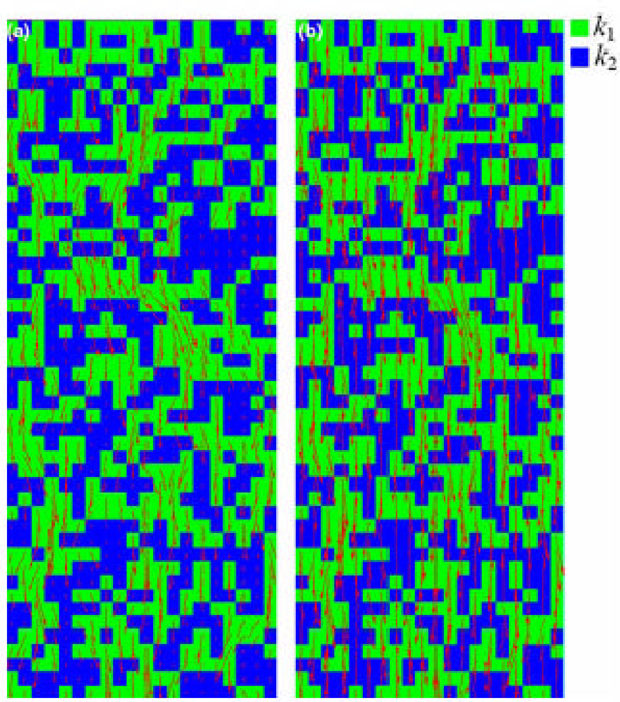


Figure 2-3 Heat Flux Vectors in EMT Model

However, the EMT approach will be attempted because if successful, it will provide a purely analytical prediction capability without a semi-empirical treatment of the widely used Krischer model.

The Krischer model is a combined semi-empirical model that allows for fitting of the model to nearly any application provided empirical data are available to solve for the appropriate value of the structural weighting factor Z. The literature refers to the Krischer model as a “flexible” model due to its ability to be tuned to nearly any application if an appropriate value of Z can be determined. Fortunately, Reference 12 contains thermal conductivity test data for all three approved coating systems used for the AP1000 plant. The thermal conductivity tests were performed in accordance with American Society for Testing and Materials (ASTM) E1530 and an approved Title 10 of the code of Federal Regulations (CFR) Part 50, Appendix B program. Therefore, as Reference 3 indicates, a very common approach for determining effective thermal conductivity is to use an empirical weighting between the parallel and series models (often referred to as the Weiner bounds), because these models represent the minimum and maximum thermal conductivity that can be achieved by a heterogeneous material. The drawback to the Krischer model is that empirical data are required to determine Z; however, if empirical data exist and the weighting factor can be accurately attuned, then the Krischer model gives excellent agreement with the data (Reference 3 and 4).

The Krischer model became well known in its application for food engineering drying technology. Food is often considered a complex fluid due to the multiple constituents associated with its composition. However, References 3 and 4 substantiate the Krischer model application to any heterogeneous material, including porous materials, provided that the shape factor can be accurately determined.

[

]a,c

2.1.2.2 Additional Considerations on Passive Containment Cooling System Performance

Some additional considerations that need to be addressed in the implementation of this model are:

- Impact on wettability due to air porosity reduction
- Impact on external containment vessel (CV) heat flux to the passive containment cooling system (PCS) fluid associated with coating growth

[

]^{a,b,c} This makes sense, because wettability is quantified by the magnitude of the three-phase angle between the characteristic water droplet, the solid surface, and the atmospheric gas (air): a reduction in the porosity within the cross section of the coating will have no impact on the “surface” wetting characteristics.

[

]^{a,c}

The following justification will demonstrate that the air porosity more than accommodates any potential for coating growth.

Reference 11 provides the [ ]^{a,b,c}, respectively. Reference 2 provides the volume fraction of zinc in the newly applied coating as [ ]^{a,c}. The density ratio can be used to determine the volumetric increase associated with complete oxidation of the zinc constituent:

a,c

[ ]

[ ]^{a,c}to:

a,c

[ ]

[

]^{a,c}

a,b,c

Figure 2-4 [ ]a,b,c

2.1.3 Method Implementation

To effectively model the degradation effects due to oxidation of the IOZ constituent of the coating system, a combined multi-stage approach should be implemented.

1. Reference 4 communicates the widely accepted method of determining an effective thermal conductivity. This method begins with the calculation of the Weiner bounds. This will be done to confirm the tested value of the coating thermal conductivity (Reference 12) is within the expected bounds formed by the parallel and series models (minimum and maximum theoretical values of the coating thermal conductivity). If the tested value of the coating thermal conductivity is not within the Weiner bounds, then certain constituents of the coating system have been left out or neglected. Further investigation into the coating constituents is required before proceeding:

    a. Calculate the material thermal conductivity of a new coating application with the parallel model.

    b. Calculate the material thermal conductivity of a new coating application with the series model.

    c. Confirm that the measured thermal conductivity lies within the Weiner bounds.

2. In theory, it is advantageous to have an analytical model that will allow for prediction of effective thermal conductivity. Due to the random distribution of the material constituents, the EMT model should be used to determine if it is a viable application for prediction of effective thermal conductivity. An uncertainty tolerance of 5 percent is recommended as compared to test data. The 5 percent is a recommendation based on engineering judgment. The uncertainty tolerance should be low enough that the combined uncertainty propagated throughout the method application would not yield a lower value than that assumed in the plant design basis analyses.

   a. Calculate the material thermal conductivity using the EMT model.

   b. Confirm that the EMT model is within the 5 percent uncertainty tolerance criterion. If the uncertainty tolerance criterion is met, proceed to Step 4; otherwise, proceed to Step 3.

3. If the uncertainty tolerance criterion is not satisfied in Step 2, then the EMT model is not accurate enough to implement. In this scenario, the empirical treatment afforded by implementation of the Krischer model must be relied upon. The empirical shape/weighting factor can be solved for by setting the Krischer model equal to the actual tested effective thermal conductivity. This will yield a valid model based on empirical data for predicting the maximum degradation associated with oxidation of IOZ in the coating system.

   It is pertinent to discuss the fact that Step 2 is not absolutely required. Successful implementation of the EMT model will allow for accurate prediction of coating performance without the necessity of empirical data. This would be advantageous in predicting the thermal conductivity of an unknown multi-constituent material with a completely random structure; however, without test data, the uncertainty tolerance criteria cannot be confirmed. The overall purpose of the EMT application in Step 2 is to demonstrate that while the cross-sectional view in Figure 2-1 indicates the potential for a loosely coupled structure, the tested thermal performance of the coating constituents do not behave in a manner consistent with that structure. As demonstrated by the large uncertainty in the EMT application, there is virtually no coupling between the high conductivity constituents.

   a. Set the Krischer model equal to the tested value for the material thermal conductivity and solve for Z, the empirical shape/weighting factor.

4. Now that the Krischer model is accurately benchmarked and an empirical shape/weighting factor is determined, the zinc constituent thermal conductivity should be replaced with the value of zinc oxide. This will conservatively model the effective thermal conductivity degradation associated with oxidation of the zinc constituent.

   a. Set $k_{Zinc} = k_{zincoxide}$ in the benchmarked Krischer model and solve for the degraded coating thermal conductivity.

5. Uncertainty propagation should be accomplished via application of square root sum of the squares (SRSS).

3 EXAMPLE APPLICATION OF METHOD

Table 3-1 shows the Carboline 11 HSN constituents, volume fractions, and thermal conductivities used in the IOZ coating system.

a,b,c

Table 3-1 [ ]a,b,c

The following Mathcad calculation , including comments, shows an example application of the methodology for the Carboline 11 HSN system:

a,b,c

Step 1

In accordance with the literature, the Weiner bounds will be established using parallel and harmonic series solutions:

To allow the k_parallel calculation to be displayed properly, the first four terms will be assigned to variable A.

a,b,c

[ ]a,b,c The tested value is within the Weiner bounds.

Step 2

To allow the EMT calculation to be displayed properly, the first six terms will be assigned to variables A and B respectively:

a,b,c

[

]^{a,c}

Step 3

[

]^{a,c}

a,b,c

Step 4

a,b,c

To allow the k_parallel calculation to be displayed properly, the first four terms will be assigned to variable A:

a,b,c

Once the Krischer model shape factor has been determined, we can substitute the zinc thermal conductivity with that of zinc oxide to understand the impact of all the elemental zinc oxidizing in the coating system:

a,b,c

Step 5

[

]a,b,c

[

]a,b,c

Conclusion

This assessment is conservative, because it preserves the new coating structure with the air porosity maximized along with the maximum accounting of uncertainty. In reality, the porosity of the coating will decrease as the zinc oxidizes and ages. This is because as the zinc combines with water vapor and air and oxidizes, the oxide will displace the air pockets due to the reduction in density of zinc oxide from elemental zinc. This is based on discussions with the Carboline coating vendor. If we assume that the air pockets are eliminated and replaced with zinc oxides based on the density ratio, the coating system thermal conductivity becomes:

a,b,c

[

]a,b,c

This demonstrates that the zinc coating based on the empirical formulation of the Krischer shape factor will cause the IOZ coating system to actually increase in thermal conductivity. [

]a,c This overly conservative approximation of the thermal conductivity increase is because as the air pockets are eliminated, the Krischer model will actually trend closer to the parallel portion of the Weiner bounds, resulting in a larger thermal conductivity than prediction.

[

]a,b,c

4 LIMITS OF APPLICABILITY

This methodology is applicable for determining the maximum thermal conductivity degradation effects associated with oxidation and aging of the IOZ coating system used on the AP1000 plant. The methodology is only applicable if all of the constituent thermal conductivities and corresponding volume fractions are known. This methodology requires empirical test data of a coating specimen (unless the EMT model meets error tolerance criteria) to appropriately implement, so that the empirical shape/weighting factor from the Krischer model can be determined.

5 CONCLUSION

In conclusion, if the methodology delineated in this document results in a value of thermal conductivity greater than the value used in the design and licensing basis analysis, the analysis value is conservative and conservatively bounds any thermal conductivity degradation effects associated with oxidation of the coating system. This is because a higher thermal conductivity is better for heat transfer. Thus, a factor of 4 reduction in the tested IOZ thermal conductivity is not required to account for the effect of oxidation. [

]a,b,c

6 REFERENCES

1. WCAP-15846, "WGOTHIC Application to AP600 and AP1000," March 2004.

2. Letter from Carboline Company, "AP1000, Carbozinc 11 HSN." August 19, 2013.

3. Wang, J.; Carson, J.; North, M.; Cleland, D., "*A new approach to modeling the effective thermal conductivity of heterogeneous materials,*" Intl. Journal of Heat and Mass Transfer 49 (2006) pg. 3075-3083.

4. Jiang, F.; Sousa A., "Effective thermal conductivity of heterogeneous multi-component materials: an SPH implementation" Heat and Mass Transfer (2007) 43 pg. 479-491.

5. Carson, J.; Lovatt, S.; Tanner, D.; Cleland, A.. "*Predicting the effective thermal conductivity of unfrozen, porous foods"* Journal of Food Engineering 75 (2006) pg. 297-307.

6. McPherson, R., A MODEL FOR THE THERMAL CONDUCTIVITY OF PLASMA-SPRAYED CERAMIC COATINGS." Thin Solid Films, 112 (1984) pg. 89-95.

7. Dunn, M.; Taya, M.; "The effective thermal conductivity of composites with coated reinforcement and the application to imperfect interfaces" Journal of Applied Physics 73 (1993) pg. 1711-1722.

8. Nan, C.; Birringer, R.; Clarke, D.; Gleiter, H.; *Effective thermal conductivity of particulate composites with interfacial thermal resistance,"* Journal of Applied Physics 81 (1997) pg. 6692-6699.

9. NSRDS-NBS 8, "Thermal Conductivity of Selected Materials" National Standard Reference Data System November 25, 1966.

10. DeWitt, D.; Incropera, F., "Introduction to Heat Transfer" 4th Edition. John Wiley & Sons, New York 2001.

11. Internet Reference: https://www.knovel.com "Yaws' Critical Property Data for Chemical Engineers and Chemists."

12. APP-GW-Z0-604 Rev. 7, "Design Specification for the Applications of Protective Coatings to Systems, Structures, and Components for All Systems Inside Containment," February 2013.

13. APP-GW-GLR-096 Rev. 3, "Evaluation of the Effect of the AP1000® Enhanced Shield Building Design on the Containment Response and Safety Analyses" June 2011.

14. Internet Reference: https://www.knovel.com "Engineering Design Handbook-Dielectric Embedding of Electrical or Electronic Components: (DARCOM-P 706-315)."

15. Internet Reference: https://www.knovel.com "Handbook of Fillers-A definitive User's Guide and Databook (2nd Edition)."

Southern Nuclear Operating Company

Vogtle Electric Generating Plant Units 3 and 4

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Enclosure 6

WCAP-15846-P, Addendum 1,
Effective Thermal Conductivity Model of Inorganic Zinc Coating
for Application to AP1000,
Revision 0, October 2013
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(Proprietary)

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(This page not proprietary.)