UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 27, 2013

David A. Heacock
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SUBJECT: KEWAUNEE POWER STATION – EVALUATION OF REPORT DESCRIBING THE NATURE OF, AND ESTIMATED EFFECT ON, PEAK CLADDING TEMPERATURE RESULTING FROM A SIGNIFICANT EMERGENCY CORE COOLING SYSTEM EVALUATION MODEL ERROR (TAC NO. ME8460)

Dear Mr. Heacock:

By letter dated March 15, 2012 (Agencywide Document Access and Management System (ADAMS) Accession No. ML12079A287), supplemented by letter dated June 8, 2012 (ADAMS Accession No. ML12164A786), Dominion Energy Kewaunee, LLC (the licensee), submitted a response to a U.S. Nuclear Regulatory Commission (NRC) information request dated February 16, 2012, made pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Paragraph 50.54(f) for Kewaunee Power Station (ADAMS Accession No. ML120410195). The submittal referred to a letter from Westinghouse Electric Company dated March 7, 2012 (ADAMS Accession No. ML12072A035), that provided additional information. The 10 CFR 50.54(f) request was related to the estimated effect on peak cladding temperature (PCT) resulting from thermal conductivity degradation in the Westinghouse-furnished realistic emergency core cooling evaluation. The letter dated March 15, 2012, also stated that the response served as a 30-day report of a significant emergency core cooling system (ECCS) evaluation model change or error, in accordance with requirements of 10 CFR 50.46(a)(3)(ii).

The NRC staff has evaluated the March 15, 2012, report, along with its supplemental information, and determined that it satisfies the reporting requirements of 10 CFR 50.46(a)(3)(ii), and also the intent of the reporting requirements, as discussed in the statement of considerations published in the *Federal Register* (FR) on September 16, 1988 (53 FR 35996), for the realistic ECCS evaluations revision of 10 CFR 50.46.

Further, the NRC staff: (1) agrees with the licensee's assessment of the significance of the error; (2) has confirmed that the evaluation model remains adequate; (3) has verified that the licensee continues to meet the PCT acceptance criterion promulgated by 10 CFR 50.46(b); and, (4) has determined that the licensee's proposed schedule for re-analysis is acceptable, in light of the information provided. The NRC staff evaluation providing the basis for these conclusions is enclosed.

This letter concludes the NRC staff efforts under TAC No. ME8460. If you have any questions on this matter, please contact me at 301-415-3079.

Sincerely,

Karl Feintuch

Karl Feintuch, Project Manager
Plant Licensing Branch III-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-305

Enclosure:
As stated

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

CLOSURE EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

DOMINION ENERGY KEWAUNEE POWER STATION

REPORT DESCRIBING THE NATURE OF

AND ESTIMATED EFFECT ON PEAK CLADDING TEMPERATURE

OF A SIGNIFICANT EMERGENCY CORE COOLING SYSTEM EVALUATION MODEL ERROR

DOCKET NO 50-305

1.0 INTRODUCTION

By letter dated March 15, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12079A287), Dominion Energy Kewaunee submitted a report describing a significant error identified in the emergency core cooling system (ECCS) evaluation model, and an estimate of the effect of the error on the predicted peak cladding temperature (PCT) for Kewaunee Power Station. This report was submitted pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Section 50.46, Paragraph (a)(3)(ii). The report was supplemented by letter dated June 8, 2012 (ADAMS Accession No. ML12164A786), and referred to a letter from Westinghouse Electric Company dated March 7, 2012 (ADAMS Accession No. ML12072A035).

The U.S. Nuclear Regulatory Commission (NRC, or Commission) staff has evaluated the report, along with its supplemental information, and determined that it satisfies the reporting requirements of 10 CFR 50.46(a)(3), and also the intent of the reporting requirements, as discussed in the statement of considerations published in the *Federal Register* (FR on September 16, 1988 (53 FR 35996), for the realistic ECCS evaluations revision of 10 CFR 50.46 The NRC staff review is discussed in the following sections of this closure evaluation.

2.0 REGULATORY EVALUATION

2.1 Requirements Contained in 10 CFR 50.46

Acceptance criteria for ECCSs for light-water nuclear power reactors are promulgated at 10 CFR 50.46. In particular, 10 CFR 50.46(a)(3)(i) requires licensees to estimate the effect of any change to, or error in, an acceptable evaluation model or in the application of such a model to determine if the change or error is significant. For the purpose of 10 CFR 50.46, a significant change or error is one which results in a calculated peak fuel cladding temperature different by more than 50 degrees Fahrenheit (°F) from the temperature calculated for the limiting transient using the last acceptable model, or is a accumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50 °F.

For each change to or error discovered in an acceptable evaluation model, or in the application of such a model, 10 CFR 50.46(a)(3)(ii) requires the affected licensee to report the nature of the change or error and its estimated effect on the limiting ECCS analysis to the Commission at least annually. If the change or error is significant, the licensee is required to provide this report within 30 days and include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with 10 CFR 50.46 requirements.

2.2 Additional Guidance

Additional clarification concerning the intent of the reporting requirements is discussed in the statement of considerations for the realistic ECCS evaluation revision of 10 CFR 50.46 (September 16, 1988; 53 FR 35996):

> [Paragraph (a)(3) of section 50.46] requires that all changes or errors in approved evaluation models be reported at least annually and does not require any further action by the licensee until the error is reported. Thereafter, although reanalysis is not required solely because of such minor error, any subsequent calculated evaluation of ECCS performance requires use of a model with such error, and any prior errors, corrected. The NRC needs to be apprised of even minor errors or changes in order to ensure that they agree with the applicant's or licensee's assessment of the significance of the error or change and to maintain cognizance of modifications made subsequent to NRC review of the evaluation model...
>
> Significant errors require more timely attention since they may be important to the safe operation of the plant and raise questions as to the adequacy of the overall evaluation model... More timely reporting (30 days) is required for significant errors or changes... this final rule revision also allows the NRC to determine the schedule for reanalysis based on the importance to safety relative to other applicant or licensee requirements.

The NRC staff considered this discussion in the *Federal Register* in its evaluation of the error report submitted by the licensee.

3.0 TECHNICAL EVALUATION

The report submitted by the licensee described the effects of an error in the ECCS evaluation model associated with the degradation of thermal conductivity in nuclear fuel. This issue is discussed in NRC Information Notice (IN) 2009-23, "Nuclear Fuel Thermal Conductivity Degradation" (ADAMS Accession No. ML091550527). Its potential effects in realistic ECCS evaluation models are described in IN 2011-21, "Realistic Emergency Core Cooling System Evaluation Model Effects Resulting from Nuclear Fuel Thermal Conductivity Degradation" (ADAMS Accession No. ML113430785).

Based on the nature of the reported error, and on the magnitude of its effect on the PCT calculation, the NRC staff determined that a detailed technical review is necessary. Based on the regulatory evaluation discussed above, the NRC staff's review was performed to ensure that it agrees with the licensee's assessment of the significance of the error, and to enable the NRC staff to verify that the evaluation model, as a whole, remains adequate.

Finally, the NRC staff's review also was to establish that the licensee's proposed schedule for re-analysis is acceptable in light of the safety significance of the reported error.

3.1 Overview of Code Qualification Document Method

The licensee evaluates ECCS performance using the NRC-approved Code Qualification Document method (CQD), which is described in WCAP-12945-P-A[1]. The CQD method relies on a statistical approach using a response surface technique, in which a reference transient is analyzed using the WCOBRA/TRAC (WC/T) computer code, and a statistically significant number of perturbations are analyzed to determine how uncertainties affect the predicted PCT. Convoluted uncertainty responses for various categories of parameters, including power distribution, plant initial conditions, and thermal hydraulic parameters, are then added to the reference transient PCT. The result is used to show compliance with the 10 CFR 50.46(b)(1) acceptance criterion concerning PCT.

3.2 Summary of Technical Information in the Report

The licensee's report indicated that the effect of the thermal conductivity degradation (TCD) error was 50 °F. The nature of the error, and the method used to estimate its effect on the calculated PCT, is discussed in greater detail in the March 7, 2012, Westinghouse letter. In the report, the licensee also discussed additional changes made to the ECCS evaluation in order to offset the effects of TCD, and to recapture margin to the regulatory limit on PCT.

TCD Error Correction

The error in the ECCS evaluation model was caused by the inability of the fuel rod performance and design (PAD), fuel performance model, to account for the effects of TCD with increasing fuel burnup. This error caused fuel temperature initial conditions to be non-conservatively low for higher burnup fuel rods that were analyzed in the ECCS evaluation. In order to correct for the error, a burnup-dependent term was added to the nuclear fuel thermal conductivity equation, which caused the predicted initial fuel temperatures to compare better with experimental data obtained from the Halden Reactor Project.[2] The results from the modified PAD (PAD 4.0 + TCD) code were then used to re-analyze the reference transient from the CQD analysis. The licensee used PAD 4.0 + TCD to generate inputs to the CQD reference transient analysis, which is different from the existing analysis. In the typical CQD analysis, the WC/T initialization generates the fuel conditions using a MATPRO-based[3] analytic procedure. The initial conditions are also calculated using PAD 4.0, and then the WC/T fuel temperature is corrected

[1] The non-proprietary version of WCAP-12945-P-A is WCAP 14747. WCAP14747 was submitted to the NRC by letter dated March 19, 1998 (ADAMS Legacy Accession No. 9804070248). The NRC staff review of WCAP-12945-P-A and WCAP-14747 is documented in a letter and evaluation dated June 28, 1996 (ADAMS Legacy Accession Nos. 9607050086 and 9607050063, respectively). ADAMS Legacy documents may be obtained from the NRC's Public Document Room.

[2] The Halden Reactor Project is an international, collaborative research project intended to gather data and information pertaining to reactor technology. Although the specific comparisons of PAD 4.0 and PAD 4.0 + TCD predictions to Halden Reactor measurements and data are Westinghouse proprietary information, related information and similar comparisons are available from the NRC's FRAPCON computer code in NUREG/CR-7022, "FRAPCON-3.4: Integral Assessment." See in particular Chapter 3 of NUREG/CR-7022.

[3] Hagrman, D.L., G.A. Reymann, and G.E. Mason, 1981. *A Handbook of Materials Properties for Use in the Analysis of Light Water Reactor Fuel Rod Behavior*, MATPRO Version 11 (Revision 2), NUREG/CR-0479 (TREE-1280), prepared by EG&G Idaho, Inc., Idaho Falls, ID, for the U.S Nuclear Regulatory Commission, Washington, D.C.

to the PAD fuel temperature by adjusting fuel rod plenum heat transfer properties. With the improved PAD correction, the STAV[4] model in WC/T is used for the initialization, instead. The STAV model more closely simulates the fuel performance predicted by PAD 4.0 + TCD than the MATPRO model.

The estimated effect of the TCD correction for Kewaunee is a 50 °F increase in the predicted PCT.

Additional Model Changes

In the submitted report, the licensee also stated that peaking factor margin changes accounted for a 115 °F reduction in the predicted PCT, and that the correction of a recently identified error associated with the HOTSPOT fuel relocation model would cause the PCT to increase by 10 °F.

Reported Results

In consideration of the effects of TCD and these additional model changes, the current PCT predicted by the ECCS evaluation for Kewaunee is 1980 °F.

3.3 Summary of Staff Evaluation

The NRC staff evaluation of the error report submitted by the licensee included a review of the report itself, a detailed audit to review the analyses supporting the report, and a request for additional information (RAI), to which the licensee responded via the June 8, 2012, letter. The NRC staff performed a detailed review of the input parameters and limiting results that were used to generate the estimate, and concluded that the estimate enables the current analysis to ensure that there is a high level of probability that the 2200 °F PCT acceptance criterion is not exceeded.

The NRC staff issued the Kewaunee licensee a total of nine RAI questions. RAI questions 1 and 4 were ultimately deleted, because the information responsive to these questions was provided in response to other RAIs. RAI questions 2 and 3 pertain to peaking factor changes, RAI questions 5 and 6 pertain to the Westinghouse analytic methods used to estimate the effects of TCD, and RAI questions 7 and 8 relate to methods used by the licensee to ensure that the ECCS evaluation, which includes the estimated effects of TCD, remains bounding of present and planned plant operation.

The final RAI question issued by the NRC staff applies to 10 CFR 50.59 processes for addressing changes to the analytic framework used in the licensing basis ECCS evaluation.

When estimating the effect of TCD and compensating changes to restore margin to regulatory limits, the licensee evaluated reduced peaking factors at beginning of life conditions. The NRC staff issued RAI 2 to obtain clarification that this evaluation strategy remains applicable at the higher burnups, where TCD becomes more significant. The licensee's response indicated that the reduced peaking factor values analyzed were limits applicable at the higher burnups, when TCD becomes more significant. The licensee's response indicated that the reduced peaking factor values analyzed were limits applicable at the beginning of life, and that the TCD effect

[4] Harris, W.R., et al. 2006. *Fuel Rod Design Methods for Boiling Water Reactors – Supplement 1, Volume 1*, WCAP-15836-NP-A, Revision 0, prepared by Westinghouse Electric Company, LLC, Pittsburgh, PA. ADAMS Accession No. ML061220455.

estimate separately included a peaking factor burndown effect, meaning that the fuel will become less peaked as it is exposed. The NRC staff determined that the response is acceptable, because it explains that the peaking factors are more limiting at beginning of life, and hence appropriate for evaluation in this condition.

The licensee provided further explanation of analyzed changes to the Kewaunee peaking factors in response to RAI 3. The response explained that a reduction in $F\Delta H$ peaking factor from 1.8 to 1.7 will bring the ECCS evaluation in line with existing core operating limits report limits[5]. The licensee also provided information, including figures, to illustrate the analyzed peaking factor burndown effect. The figures showed analytic limits assumed in the ECCS evaluation, and compared the limits to design values for F_Q and $F\Delta H$ for three cycles. In addition to illustrating that the cycle-specific design values were bounded by the analyzed limits, the figures also showed a tendency for the margin between the analyzed limits and the design values to increase with burnup. The NRC staff determined that the licensee's response was acceptable because it shows that the cycle-specific core designs are bounded by the analyzed limits when crediting the peaking factor burndown effects.

To estimate the effect of TCD using a more generic model that is more feasibly implemented, the licensee used a representative fuel rod design. In response to RAI question 5a, the licensee provided information comparing the representative fuel rod type to Kewaunee-specific fuel rod design characteristics (Enclosure 2 to June 8, 2012, letter). The information demonstrated that the representative rod was mostly the same as the Kewaunee-specific design. Where deviations were identified, the licensee indicated that the representative rod was bounding on the Kewaunee design, with one exception. For the design characteristic, for which the representative rod was non-bounding, the licensee provided additional explanation that showed that other, more bounding characteristics offset the effects of the unbounded characteristics. Based on its review of the information provided by the licensee, the NRC staff determined that the response to 5a was acceptable, because it demonstrated the acceptability of using a representative fuel rod design to estimate the effects of TCD.

In response to NRC RAI 5b, the licensee provided values for coefficients used in the PAD 4.0 + TCD uranium dioxide thermal conductivity equation (Enclosure 2 to June 8, 2012, letter). The information provided by the licensee allowed the NRC staff to verify that the thermal conductivity equation had been adjusted in a way that reflected the available experimental data. Figures included with the RAI response also showed reasonable agreement between the TCD-corrected versions of PAD and HOTSPOT in comparison to FRAPCON calculations. Based on these considerations, the NRC staff finds the response to RAI 5b acceptable.

In response to NRC RAI 5c, the licensee provided reports documenting error corrections, code improvements, and miscellaneous code cleanup affecting WC/T and HOTSPOT between the time that the analyses of record were performed and the TCD estimates were generated. The NRC staff requested this information because the enclosure to the March 7, 2012, Westinghouse letter referred to these changes in a general sense, and the staff determined that additional detail was necessary to verify that the code changes would not affect the TCD estimate in unintended ways. The NRC staff reviewed the provided documentation and did not identify any code changes referenced in the Westinghouse letter that would affect the validity of

[5] This reduction in assumed $F\Delta H$, which is a core peaking factor, has the effect of reducing the peak linear heat rate assumed in the ECCS evaluation. This change will lessen the predicted severity of the results of the ECCS evaluation, but is acceptable since the changed value is in line with core operating limits.

the TCD estimate. Based on this consideration, the NRC staff finds the licensee's response to NRC RAI 5c acceptable.

In response to NRC RAI 5d, the licensee stated that the code changes discussed in the previous paragraph did not affect the fuel thermal conductivity model, but that using a more recent HOTSPOT code version is appropriate because certain error corrections affect the TCD effect estimate. The licensee provided a fuel relocation error correction as an example. Correction of a fuel relocation error would cause the TCD estimate to be more realistic in that the energy stored in the fuel is affected by the amount of fuel present at a given location. Therefore, the NRC staff finds that the licensee's response to RAI 5d is acceptable.

In response to RAI 5e, the licensee provided additional detail about the validity of the corrected UO_2 thermal conductivity model in each code, since the models are different and may be implemented differently within each code. The licensee's response explained that the technical basis for each model was the same, and clarified that the differences between the models were minor. The licensee's response included graphs that compared the predicted UO_2 thermal conductivity between FRAPCON 3.4, and the corrected versions of HOTSPOT and PAD. The NRC staff reviewed the information and concluded that the UO_2 thermal conductivity models produced similar results and were reasonably valid as compared to FRAPCON 3.4. Based on this information, the NRC staff determined that the RAI response was acceptable.

In response to RAI 6, the licensee provided information describing the procedure and incremental adjustments that are performed within WC/T and HOTSPOT to obtain steady-state convergence. While most of the information described minor adjustments to boundary conditions to obtain convergence in the system state properties, a portion of the response described adjustments made to ensure that the fuel stored energy predicted in HOTSPOT agrees with the result predicted in WC/T. The information clarified that any adjustments made in the HOTSPOT calculations were typically minor, and that, because of the similarities in the HOTSPOT and WC/T fuel performance models, the adjustments usually resulted in similar state properties used by both codes. The NRC staff determined that this response was acceptable because it indicated that both HOTSPOT and WC/T were relying on similar properties when initiating the large-break loss-of-coolant accident (LBLOCA) transient calculations.
The NRC staff issued RAIs 7 and 8 to determine how the licensee would ensure that any changed design limits or other input values would remain applicable to the operating cycles at Kewaunee.

In response to the RAI questions, the licensee provided a detailed explanation of cycle design and operating surveillance processes. The cycle design processes ensure that specific cycle designs conform to the limits established by the LBLOCA analyses, which now account for TCD effects. The surveillance processes ensure that the core operates as designed throughout the cycle. In combination, the design and surveillance processes ensure that the core remains within revised limits associated with the TCD effect estimate. Because the licensee provided information indicating that the cycles will be designed and surveilled in a manner that ensures adherence to revised limits associated with the effects of TCD, the NRC staff determined that the responses to RAI questions 7 and 8 were acceptable.

The licensee provided a commitment to perform a re-analysis, stated as follows:

> Before December 15, 2016, DEK [Dominion Energy Kewaunee] will submit to the NRC for review and approval a LBLOCA analysis that applies an NRC-approved ECCS Evaluation Model that includes the effects of fuel thermal conductivity degradation.

Since the licensee's evaluation is based on a rigorous analytic approach, the NRC staff finds that the licensee has demonstrated that the effects of the error are appropriately estimated, and that the licensee has provided assurance that it will not exceed 2200 °F following a LOCA. In addition, the NRC staff collects and trends information reported pursuant to 10 CFR 50.46(a)(3)(ii), concerning ECCS evaluation model changes and errors. The NRC staff may find that it is necessary to revisit this conclusion if other significant errors in the CQD evaluation model are reported.

The re-analysis requirement contained in 10 CFR 50.46(a)(3)(ii) states the following:

> ...and [the licensee] shall include with the report a proposed schedule for providing a reanalysis or taking other action as may be needed to show compliance with [10 CFR] 50.46 requirements.

Although a Regulatory Commitment is not explicitly necessary to address this requirement, the statement provided by the licensee satisfies this requirement by indicating a proposed date that a re-analysis will be provided. Further, the NRC staff finds that the proposed re-analysis date is commensurate with the safety significance of the issue, based on the considerations described above. Therefore, the NRC staff finds that the licensee has adequately addressed the re-analysis requirement contained in 10 CFR 50.46(a)(3)(ii).

CONCLUSION

Based on the considerations discussed above, the NRC staff finds that the report submitted pursuant to 10 CFR 50.46(a)(3)(ii), concerning an ECCS evaluation model error pertaining to TCD, satisfies the intent of the 10 CFR 50.46 reporting requirements. The submittals dated March 7, 2012, March 15, 2012 and June 8, 2012, enabled the staff to (1) determine that it agrees with the licensee's assessment of the significance of the error, (2) confirm that the evaluation model remains adequate, (3) verify that the licensee continues to meet the PCT acceptance criterion promulgated by 10 CFR 50.46(b), and (4) determine that the licensee's proposed schedule for re-analysis is acceptable in light of the information provided.

Principal Contributor: Benjamin Parks

Date of issuance: February 27, 2013

This letter concludes the NRC staff efforts under TAC No. ME8460. If you have any questions on this matter, please contact me at 301-415-3079.

Sincerely,

/RA/

Karl Feintuch, Project Manager
Plant Licensing Branch III-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-305

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