ENCLOSURE 1

MFN 12-117

Implementation of PRIME Models and Data in Downstream Methods, NEDO-33173, Supplement 4-A, Revision 1, November 2012

Non-Proprietary Information - Class I (Public)

GE Hitachi Nuclear Energy

NEDO-33173 Supplement 4-A
Revision 1
eDRF Section 0000-0103-4574 R2
November 2012

Non-Proprietary Information - Class I (Public)

Licensing Topical Report

IMPLEMENTATION OF PRIME MODELS AND DATA IN DOWNSTREAM METHODS

October 22, 2012

Mr. Jerald G. Head
Senior Vice President, Regulatory Affairs
GE-Hitachi Nuclear Energy Americas, LLC.
P.O. Box 780, M/C A-18
Wilmington, NC 28401-0780

SUBJECT: NRC AUDIT OF GE-HITACHI NUCLEAR ENERGY AMERICAS TOPICAL REPORT NEDO-33173, SUPPLEMENT 4-A, "IMPLEMENTATION OF PRIME MODELS AND DATA IN DOWNSTREAM METHODS" (TAC NO. ME9033)

Dear Mr. Head:

By letter dated September 12, 2011 (Agencywide Documents and Access Management System (ADAMS) Accession No. ML112440229), the U.S. Nuclear Regulatory Commission (NRC) staff issued its final Safety Evaluation (SE) approving GE-Hitachi Nuclear Energy Americas (GEH) Topical Report NEDO-33173, Supplement 4, "Implementation of PRIME Models and Data in Downstream Methods." By letter dated September 23, 2011 (ADAMS Accession No. ML112660155), GEH submitted the approved ("-A") version of this TR to the NRC, incorporating the NRC staff's final SE. Supplement 4 provided a detailed plan for implementation of PRIME fuel rod thermal-mechanical (T-M) models in downstream analysis codes. The PRIME T-M models would replace legacy models (e.g., GSTRM) within downstream analysis codes that do not account for fuel thermal conductivity degradation. In its review of NEDO-33173, Supplement 4, the NRC staff found the scope of the PRIME implementation plan acceptable. The NRC staff's SE for NEDO-33173, Supplement 4 included the following statement:

> At the conclusion of the code update and software testing process the NRC staff will audit the final documentation to ensure that the code updates were performed in accordance with the approved process described in Supplement 4.

On July 17 and 18, 2012, at GEH facilities in Wilmington, NC and Washington, DC, the NRC staff conducted an audit of the PRIME implementation in downstream analysis codes in accordance with the audit scope defined in the above Supplement 4 SE conclusion. During this audit, the NRC staff reviewed PRIME implementation with regard to:

(1) Encoding of PRIME conductivity models;
(2) Steady-state nuclear methods;
(3) Transient analyses;
(4) Emergency core cooling system / loss-of-coolant accident performance;
(5) Stability; and
(6) GEH's plan to implement PRIME with licensee reload designs.

In each of these areas, the NRC staff found the PRIME models had been correctly implemented and found the implementation plan acceptable. The NRC staff's audit of GEH's PRIME implementation into downstream safety analysis analytical methods found that the NEDO-33173, Supplement 4 plan was correctly executed. The PRIME conductivity models were correctly encoded into downstream applications and test cases demonstrated that the impact of switching from GSTRM to PRIME models was as expected. There were no open items or negative audit findings.

This letter documents the completion of the NRC staff's audit and satisfies the condition stated above and in the conclusion of the NRC staff's SE for NEDO-33173, Supplement 4. We request that GEH publish a revision of NEDO-33173, Supplement 4-A, and include this letter with the NRC staff's final SE after the title page.

Sincerely,

/RA/

Sher Bahadur, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No.: 710

cc: See next page

were correctly encoded into downstream applications and test cases demonstrated that the impact of switching from GSTRM to PRIME models was as expected. There were no open items or negative audit findings.

This letter documents the completion of the NRC staff's audit and satisfies the condition stated above and in the conclusion of the NRC staff's SE for NEDO-33173, Supplement 4. We request that GEH publish a revision of NEDO-33173, Supplement 4-A, and include this letter with the NRC staff's final SE after the title page.

Sincerely,

/RA/

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Office of Nuclear Reactor Regulation

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ADAMS Accession Number: ML12277A401 **NRR-043**

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September 9, 2011

Mr. Jerald G. Head
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SUBJECT: FINAL SAFETY EVALUATION FOR GE HITACHI NUCLEAR ENERGY AMERICAS TOPICAL REPORT NEDO-33173, SUPPLEMENT 4, "IMPLEMENTATION OF PRIME MODELS AND DATA IN DOWNSTREAM METHODS" (TAC NO. ME1704)

Dear Mr. Head:

By letter dated July 10, 2009 (Agencywide Documents Access and Management System Accession No. ML091910490), GE Hitachi Nuclear Energy Americas (GEH) submitted Topical Report (TR) NEDO-33173, Supplement 4, "Implementation of PRIME Models and Data in Downstream Methods," to the U.S. Nuclear Regulatory Commission (NRC) staff. By letter dated July 16, 2010, an NRC draft safety evaluation (SE) regarding our approval of TR NEDC-33173P, Supplement 4, was provided for your review and comment. By letter dated September 30, 2010, GEH responded indicating that it had no comments on the draft SE.

The NRC staff has found that TR NEDC-33173P, Supplement 4, is acceptable for referencing in licensing applications for GEH-designed boiling water reactors to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that GEH publish an accepted version of this TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed final SE after the title page. Also, the accepted version must contain historical review information, including NRC requests for additional information (RAI) and your responses. The accepted version shall include an "-A" (designating accepted) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, GEH and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

/RA/

Robert A. Nelson, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 710

Enclosure:
Final SE

cc w/encl: See next page

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2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

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/RA/

Robert A. Nelson, Deputy Director
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Office of Nuclear Reactor Regulation

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APPENDIX L – SAFETY EVALUATION OF SUPPLEMENT 4 TO NEDO-33173

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

NEDO-33173, SUPPLEMENT 4

"IMPLEMENTATION OF PRIME MODELS AND DATA IN DOWNSTREAM METHODS"

GE-HITACHI NUCLEAR ENERGY AMERICAS LLC

PROJECT NO. 710

1 Introduction and Background

General Electric (GE, now GE–Hitachi Nuclear Energy Americas (GEH) / Global Nuclear Fuel (GNF)) submitted the GESTR-MECHANICAL (GSTRM) model as part of the GESTR-LOCA and SAFER models licensing topical report (LTR) to the U.S. Nuclear Regulatory Commission (NRC) staff for review and approval on December 30, 1977 (Reference 1). This LTR described the basic models and calculational framework that represent the GSTRM methodology. The NRC staff reviewed the GSTRM code consistent with the applicable regulatory guidance and issued its safety evaluation (SE) on November 2, 1983 (Reference 1). GE submitted the GSTRM method as an alternative method to the TEXICO fuel rod model approved in 1972 (Reference 2).

The GSTRM model incorporates a fuel rod thermal model, a fuel rod mechanical model, a fission gas release model, and a fuel rod internal pressure model. These models are comprised of several empirical relationships for material physical properties and equations that describe relevant physical processes such as thermal conduction or cladding strain. The properties themselves are treated in the code as correlated parameters based on various test data. For example, the fuel pellet thermal conductivity is treated as an analytic expression in terms of the fuel temperature. The GSTRM LTR describes the integral qualification of the GSTRM predictive capabilities relative to test data (Reference 1).

The NRC staff approved GSTRM with the understanding that models within GSTRM would be revised to reflect more modern test data as these data became available and to be representative of future fuel rod designs. The NRC staff accepted the use of a significance test to determine whether NRC review and approval of model revisions was warranted. In 1984, GE submitted to the NRC the five significance test criteria for GSTRM model revisions (Reference 3). Similarly, in 1984, GE submitted the changes that were made to GSTRM

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between the approval of the GESTR-LOCA mechanical model and the code version referenced in the GESTAR Amendment 7 (Reference 4). The NRC staff accepted these model revisions as being within the scope of allowed changes as determined by the significance test criteria (Reference 5). Note that these significance test criteria were accepted and used to approve the model revisions and transition to GSTRM, but were not used to evaluate further model revisions or considered in this SE for the transition to the PRIME model.

In its review of the GESTAR amendment incorporating GSTRM into the GEH/GNF standard reload safety analysis process, the NRC staff noted that because GSTRM is so fundamental to GEH/GNF's fuel analysis work, a transition was needed from the Amendment 6 TEXICO approach to the Amendment 7 GSTRM approach. In its SE approving Amendment 7 to GESTAR, the NRC staff required that GE submit an implementation schedule within three weeks of issuance of the SE (Reference 5).

In the NRC staff SE of GEH LTR NEDC-33173P-A, Revision 1 (hereafter, the interim methods licensing topical report (IMLTR)) (Reference 6), the NRC staff evaluated the applicability of the GSTRM thermal-mechanical (T-M) methodology to expanded operating domains. During its review of the IMLTR, the NRC staff imposed Limitation 12 in its approving SE. Limitation 12 states:

> In MFN 06-481 [Reference 7], GE [now GEH] committed to submit plenum fission gas and fuel exposure gamma scans as part of the revision to the T-M licensing process. The conclusions of the plenum fission gas and fuel exposure gamma scans of GE 10X10 fuel designs as operated will be submitted for NRC staff review and approval. The revision will be accomplished through Amendment to GESTAR II [Reference 8] or in a T-M licensing LTR. PRIME (a newly developed T-M code) has been submitted to the NRC staff for review [References 9, 10, and 11]. Once the PRIME LTR and its application are approved, future license applications for EPU [extended power uprate] and MELLLA+ [maximum extended load line limit analysis plus] referencing LTR NEDC-33173P must utilize the PRIME T-M methods.

The PRIME model and its application were approved by the NRC staff as documented by letter dated January 22, 2010 (Reference 12). By letter dated February 27, 2009, GEH committed to issue a supplement to the IMLTR that describes the implementation of the PRIME code models and inputs into the downstream safety analysis codes (Reference 13). The purpose of the supplement is to address Limitation 12 from the NRC staff's SE to the IMLTR, which requires the use of the PRIME T-M methods in future license applications for EPU and MELLLA+ now that PRIME and its application are approved. GEH submitted the implementation plan as Supplement 4 to the IMLTR (hereafter, Supplement 4) for NRC review and approval by letter dated July 10, 2009 (Reference 14).

2 Regulatory Evaluation

Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.34, "Content of applications; technical information," provides requirements for the content of safety analysis reports for operating reactors. The purpose of the IMLTR is to provide a licensing basis that allows the NRC to issue SEs for expanded operating domains including constant pressure and/or EPU and MELLLA+ applications. The SE for the IMLTR approves the use of GEH/GNF methods for expanded operating domains. A licensee applying for an EPU or MELLLA+ licensing amendment may refer to the IMLTR as a basis for the license change request regarding the applicability of GEH/GNF methods to the requested changes.

During its review of the IMLTR, the NRC staff specified limitations and conditions in the approving SE that clarify the extent of the NRC staff's approval of the IMLTR. A licensee referencing the IMLTR must demonstrate compliance with the limitations and conditions to ensure that the licensee's specific application of the IMLTR is within the scope of the NRC staff's approval.

Supplement 4 to the IMLTR provides for a generic disposition of Limitation 12 specified in the NRC staff's SE. Therefore, the NRC staff reviewed Supplement 4 as a generic disposition to the limitation such that plant-specific applications for EPU and MELLLA+ referencing the IMLTR do not need to provide a plant-specific disposition when the IMLTR (as supplemented) is referenced in license applications.

In the current review, the NRC staff considered Supplement 4 as providing a method to update a method, and is similar to the method for updating T-M methods as proposed by GE for GSTRM in Reference 3. Similarly, Supplement 4 provides an implementation plan to update T-M related methodologies, and is similar to the implementation plan for GSTRM required by the NRC staff in Reference 5. The NRC staff leveraged its experience from the GSTRM review in this review.

With regard to updating the suite of approved methods, the NRC staff also considered the regulatory requirements of: 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," as related to quality assurance (QA); 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems [ECCS] for light-water nuclear power reactors," for loss-of-coolant accident (LOCA) evaluation model changes and associated reporting requirements; and 10 CFR 50.59, "Changes, tests, and experiments," regarding changing a method of evaluation in the safety analysis.

3 Technical Evaluation

The Supplement 4 implementation plan describes a process for cascading an NRC-approved, updated fuel thermal performance model into the downstream analysis codes. Therefore, the NRC staff review does not consider the nature of the fuel thermal performance model itself. The NRC staff notes that the approval of this process requires that the approved PRIME models be implemented.

The NRC staff technical evaluation is organized according to generic aspects of the implementation plan with separate sections to discuss those aspects of the plan that are specific to different safety analyses (e.g., steady-state or transient).

The NRC staff considered in its review whether the code updates were sufficient to meet the intent of Limitation 12 and consistent with the criteria of 10 CFR 50.59 in terms of analysis method changes on a code-specific basis. Additionally, the NRC staff reviewed the processes to ensure consistency with the QA requirements of the internal GEH/GNF procedures and 10 CFR 50, Appendix B, on a generic basis.

3.1 Generic Implementation and Testing Approach

Supplement 4 provides the plan for implementation of PRIME T-M models in downstream codes. The T-M models that are utilized in downstream analyses are incorporated in order to evaluate fuel and cladding temperatures and fuel rod surface heat flux. The fuel thermal conductivity model and the gas gap conductance information are translated from the T-M methodology. Therefore, the plan for the downstream analysis methods considers the implementation and testing of PRIME thermal conductivity models and the gas gap conductance data (Reference 14). The NRC staff agrees with this GEH determination and therefore finds that the scope of the generic implementation is appropriate for the types of analyses that are performed using the downstream methods.

The NRC staff finds that updating the fuel thermal models in the suite of downstream codes for consistency with PRIME constitutes a change in a method of evaluation to another method that has been approved by the NRC staff for the intended application. Therefore, per 10 CFR 50.59(c)(2)(viii), the method changes may be performed without NRC review and approval since the PRIME model has been approved by the NRC staff separately.

The general approach for PRIME implementation in the downstream analysis codes is to encapsulate the PRIME subroutine for thermal conductivity and to replicate this model in the other codes. The PRIME model determines the conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, plutonium concentration, fraction of theoretical density, and fuel melting temperature. The PRIME subroutine implemented in the downstream codes will be somewhat simplified in that it will only consider temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density (Reference 14). The NRC staff finds that for downstream reactor core and systems analyses, these parameters provide for sufficient characterization of the fuel thermal conductivity. This approach inherently assumes that the plutonium concentration is zero; therefore, it does not consider mixed-oxide fuel.

PRIME generates dynamic gas gap conductance output. The general approach for implementing this data in downstream analyses is to utilize the PRIME output rather than replicate the PRIME models for gas gap conductance in the downstream codes. The NRC staff has reviewed a similar approach for TRACG analyses (Reference 15) and has found this strategy acceptable for performing downstream transient calculations. A parallel approach for other downstream codes as outlined in Supplement 4 is likewise acceptable on the same basis.

When updating the downstream codes with the simplified PRIME thermal conductivity model and capability to utilize the PRIME gas gap conductance output, the codes will maintain the previously approved internal models as an optional capability. This allows for backwards compatibility and the capability to perform sensitivity studies.

Supplement 4 also provides generic requirements for software testing once the PRIME models and relevant output data are incorporated in the downstream codes. The implementation plan specifies that GEH will adhere to the approved QA procedures. Therefore, the NRC staff is reasonably assured that these code changes will meet the QA requirements of 10 CFR 50, Appendix B.

Supplement 4 also provides specific generic testing requirements for the code updates. The software testing considers: (1) testing of the PRIME models to ensure that the model, as coded, generates appropriate properties over the range of application; (2) process changes necessary to provide any additional inputs, such as providing PANAC11-generated nodal exposure information to downstream transient and accident codes; (3) comparison of the application process using PRIME relative to the previous method; (4) comparison of the code's sensitivity to similar sensitivities predicted using TRACG; and (5) the significance of the changes considering the process for including uncertainties.

The NRC staff has reviewed these generic requirements and determined that their scope is comprehensive in that it considers the individual code performance as well as the interfaces between the individual codes. Additionally, the requirements specify comparison against sensitivity results produced by TRACG. The TRACG04 code was selected to perform this sensitivity analysis in part because the code already includes a capability for utilizing the PRIME thermal conductivity model and also because the NRC staff has reviewed various capabilities of TRACG to perform a wide variety of transient and safety analyses.

The NRC staff accepts the use of TRACG04 for this purpose since the physical bases for the TRACG04 models are significantly similar to the bases for those models included in the other codes (i.e., ODYN, SAFER, and others). Therefore, the NRC staff expects that the TRACG04 code, given that it has more detailed modeling capabilities (i.e., three-dimensional kinetics), will yield the most accurate assessment of the physical sensitivity of the transient and accident plant response to differences in the fuel thermal model.

The NRC staff acceptance of the usage of TRACG04 to determine the sensitivity of the relevant figures of merit does not herein constitute NRC approval of TRACG04 to perform licensing safety analysis.

Supplement 4 states that the sensitivity test is intended to be representative such that comprehensive requalification is deemed unnecessary. The NRC staff finds that this approach is reasonable. The NRC staff has reviewed a series of sensitivity studies performed using TRACG04 during its review of GEH's response to Request for Additional Information 39 from the PRIME LTR review (Reference 16). Referencing these limited sensitivity studies as a basis for expected code sensitivity, the NRC staff finds that it is reasonable to perform a limited set of code tests and that comprehensive requalification is not necessary to provide reasonable assurance of the modified code performance.

On these bases, the NRC staff has concluded that the implementation plan: (1) appropriately translates the fuel thermal models for the important phenomena from PRIME to downstream codes, (2) is consistent with the QA requirements of 10 CFR 50, Appendix B, (3) is sufficiently comprehensive in scope to validate the existing qualification and test all necessary performance aspects, and (4) includes a technically justifiable standard approach for all of the downstream analyses of interest. Therefore, the NRC staff finds the generic aspects of the implementation plan acceptable.

3.2 Fuel Thermal Mechanical

PRIME03 is intended to directly replace the GSTRM code for stand-alone fuel T-M analyses. Therefore, no specific updates are required in the code stream to ensure consistency with PRIME at the fuel T-M analysis level. However, the remainder of Supplement 4 describes the specific changes in downstream codes that rely on similar models, data, or direct code output from the T-M analysis to make these downstream codes consistent with PRIME.

3.3 Steady-State Nuclear Methods

The steady-state nuclear design methods include the TGLBA06 and PANAC11 codes. These codes are referred to as the "Improved Steady-State Methods," and were approved by the NRC in Reference 17.

3.3.1 TGBLA

TGBLA06 is a lattice physics code that is used to develop nuclear data used by the downstream PANAC11 code to perform detailed nuclear design calculations. The fuel thermal conductivity formulation does not have any impact on the calculations performed in TGBLA06. TGBLA06 is used to generate nuclear parameters as a functional form of several lattice average parameters, including the average fuel temperature. To perform this calculation, TGBLA06 is not used to evaluate the fuel temperature, but instead is used to calculate the variation in lattice-averaged nuclear parameters as a function of user-input fuel temperature (Reference 14). Therefore, the NRC staff agrees with the determination of Supplement 4 that no code changes are required for TGBLA06 to implement the PRIME models in downstream codes.

3.3.2 PANACEA

PANAC11 is a three-dimensional core simulator based on 1.5 group nodal diffusion theory (Reference 17). In the calculation of the eigenvalue and power distribution, PANAC11 does not directly model the heat conduction through the fuel pellets. Rather, PANAC11 incorporates a simplified model that relates the average nodal fuel temperature with the nodal power level. This simplified model is incorporated to capture the effect of Doppler reactivity feedback on nodal power distribution.

According to Supplement 4, the Doppler feedback is not a strong reactivity contribution relative to the void reactivity effect at steady-state conditions for boiling water reactor (BWR) applications. Therefore, should the fuel temperature relationships be updated to reflect the PRIME models, it is expected that the affect on the power distribution and eigenvalue calculations would be negligible (Reference 14).

Supplement 4 states that the current simplified approach remains reasonable for steady-state applications. On the basis of engineering judgment and the understanding of the significant differences between the magnitude of the void and Doppler reactivity feedback coefficients, the NRC staff agrees that it is reasonable to assume that the effect of updating the PANAC11 models would be negligible. However, the Supplement 4 implementation plan provides for specific investigation of the impact of the difference between PRIME and GSTRM-based heat flux tables in the PANAC11 calculations. The NRC staff finds that this approach is prudent and will provide a robust technical basis for the determination of the insensitivity of the PANAC11 calculational results to the specific treatment of the nodal fuel temperature.

As part of the investigation, PRIME-based heat flux tables will be generated and a representative GNF fuel loaded core analysis will be performed over several cycles. The analysis will compare hot and cold eigenvalues and traversing in-core probe measurements to GSTRM and PRIME-based calculations. This approach is taken since Doppler effects may impact exposure accrual; therefore, one or more cycles will be simulated (Reference 14). The NRC staff finds that this comparison basis captures the important phenomena and provides a systematic means to assess the code sensitivity.

On these bases, the NRC staff finds that: (1) it is reasonable to proceed with the implementation of PRIME under the assumption that modifications to PANAC11 will not be necessary, (2) the investigation provided in the plan provides for a robust technical verification of the engineering judgment basis for the current plan, and (3) there is reasonable assurance that the planned approach for PANAC11 will yield acceptably accurate results for downstream analyses.

The NRC staff notes that as part of the implementation plan an audit will be conducted at the conclusion of the code updates. As part of this audit, the NRC staff will review the results of the GEH study of the effects of the PRIME/GSTRM-based heat flux tables on the PANAC11 results in order to verify the adequacy of the approach.

3.4 Transient Analysis

3.4.1 ODYN

ODYN is a one-dimensional coupled kinetics and thermal-hydraulics code that is used to perform transient calculations such as anticipated operational occurrence (AOO), American Society of Mechanical Engineers (ASME) overpressure, and anticipated transient without scram (ATWS) analyses. The ODYN methodology and its approval are described in Reference 18.

The current fuel thermal conductivity formulation in ODYN is a built-in table of thermal conductivity as a function of temperature. The only user input is a global multiplier on fuel and clad thermal conductivity. ODYN will be modified with a switch to select the PRIME-based fuel thermal conductivity. With this option selected, ODYN will use the PRIME-based thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density. The NRC staff finds that this approach is acceptable.

The additional arguments necessary to supply the PRIME model (e.g., exposure) will be supplied by either the user or retrieved from PANAC11 output files. The NRC staff finds either approach acceptable.

The ODYN gap conductance is based on a core average value with optional axial multipliers. This model will not be changed except that the values will be supplied by upstream PRIME calculations instead of GSTRM calculations. The NRC staff finds this approach acceptable.

3.4.2 TASC

TASC is a single channel code that is part of the overall transient analysis methodology. This code is specifically used to evaluate thermal-hydraulic performance for a single channel. It is used in the evaluation of critical heat flux onset or margin (Reference 19).

According to Supplement 4, TASC will be modified to employ a similar strategy as ODYN for the PRIME-based fuel thermal conductivity calculation. This is acceptable. As for the gap conductance, constant values that vary axially are input. These inputs will be revised to be consistent with the PRIME-calculated values and no code modifications are required.

3.4.3 Implementation and Testing

Transient-specific testing will include both ODYNM10 and ODYNV09. Limiting critical power ratio (CPR) transients and ATWS simulations will be performed. These analyses couple ODYN and TASC. The comparisons of transient minimum CPR and ATWS peak cladding temperature (PCT) provide an integral test of the coupled ODYN/TASC code system for transient applications. The NRC staff has reviewed the transient-specific test requirements in Reference 14 and finds that the selection of these transients provides a reasonable subset of the application range to be representative. Further, the NRC staff agrees with the implementation plan that these cases will provide an integral assessment of the ODYN and TASC codes.

3.4.4 TRACG

TRACG may be used for several analysis applications (References 20, 21, and 22). These include transients and stability, and GNF plans to submit TRACG application LTRs for operating fleet ECCS/LOCA analysis and ATWS analysis beyond the time of peak pressure (References 14 and 23). The NRC staff has recently reviewed the LTR describing the application of TRACG04 to perform transient analyses. These include AOOs, ATWS overpressure, and ASME overpressure analyses (Reference 15).

The TRACG04 application described by the Migration LTR (Reference 15) includes input options that allow for use of a PRIME-based thermal conductivity model with PRIME-generated gas gap conductance input. Therefore, no changes to the TRACG code are required to implement PRIME in the downstream transient and accident applications. The NRC staff review of the Migration LTR is documented in Reference 15. In its review, the NRC staff imposed the condition that consistent gas gap conductance and fuel thermal conductivity input options must be specified, and that once PRIME is approved, the TRACG calculations be performed using the PRIME thermal conductivity model and gas gap conductance file.

Supplement 4 states that TRACG will not be modified for PRIME implementation (Reference 14). This is fully consistent with the previous NRC staff review of TRACG04 as part of the Migration LTR. Therefore, the NRC staff finds that the implementation plan in terms of TRACG is acceptable.

3.5 Stability

3.5.1 ODYSY

ODYSY is a frequency domain linearized perturbation code that is used to assess thermal-hydraulic instability margin. The ODYSY code is based on the ODYN code and solved in the frequency domain to determine the reactor decay ratio (References 24 and 25).

3.5.1.1 Model Updates

ODYSY allows the input of gap conductance for each axial level of each channel group. Typically, however, a core average value with simple power dependence is utilized. Only the supplied input will change for the PRIME-based gap conductance implementation.

Currently, ODYSY can calculate the fuel thermal conductivity as a function of temperature and gadolinia concentration. ODYSY will be modified with a switch to select the PRIME-based fuel thermal conductivity. With this option selected, ODYSY will use the PRIME-based thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density.

This approach is largely similar to the ODYN/TASC updates and likewise acceptable to the NRC staff.

3.5.1.2 Implementation and Testing

ODYSY05 testing will consider representative analyses of reload licensing evaluations performed for Option I-D, Option II, Option III, and detect and suppress solution – confirmation density long-term stability solution plants. These calculations will consider the decay ratio as a figure of merit (Reference 14). The NRC staff expects that the PRIME and GSTRM-based calculations will yield different results given the sensitivity of stability calculations to the fuel thermal time constant. In terms of its review, however, the NRC staff has found that this scope of testing is sufficient to cover the range of application of ODYSY, and is therefore acceptable.

3.5.2 TRACG

TRACG is applied to several transient and accident analyses. The implementation of PRIME with TRACG discussed in Section 3.4.4 of this SE is applicable to stability analyses.

3.6 Emergency Core Cooling System / Loss-of-Coolant Accident Performance

The basis for the Appendix K ECCS/LOCA evaluation model is SAFER/GESTR (Reference 1). The purpose of the SAFER code is to calculate long-term reactor vessel inventory and PCT for LOCA and loss of inventory events. SAFER is intended for use with GSTRM to perform ECCS/LOCA analyses. The various individual codes utilized in the ECCS/LOCA evaluation model are depicted in Figure 1. The GESTR-LOCA fuel rod model mentioned in Figure 1 is equivalent to GSTRM.

3.6.1 SAFER

Supplement 4 describes one update to the SAFER model. The code will be modified to include an option to select the PRIME-based fuel thermal conductivity model as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density. Inputs to the SAFER code may provide a full description of the fuel initial conditions and are therefore sufficient to drive the PRIME-based model in the ECCS/LOCA calculations. The NRC staff finds this acceptable.

The SAFER code includes several options to model the gap conductance. In the current approach, the dynamic gap conductance model will be used and no changes are therefore required in SAFER. The approach proposed in Supplement 4 will be to supply input to SAFER from PRIME calculations of the gap conductance. The NRC staff likewise finds this approach acceptable.

3.6.2 CORECOOL

The CORECOOL code (CORCL) is used to perform PCT calculations under conditions of spray cooling during LOCA simulations (References 26 and 27). Information to run CORCL is typically provided by SAFER calculations through interface files in the standard analysis process. As a consequence of this linkage, gas gap conductance information from SAFER is passed directly to CORCL. Therefore, no modifications are required for CORCL to account for the PRIME-based gap conductance models given the changes to the SAFER input described above.

Several options exist within CORCL to model the fuel thermal conductivity. In the approach described in Supplement 4, CORCL will be modified with an option to select the PRIME-based fuel thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density. The NRC staff finds that this approach is acceptable.

3.6.3 Implementation and Software Testing

No ECCS/LOCA analysis specific testing requirements are described in the current approach. However, the NRC staff has reviewed the generic requirements and found that these are sufficient to demonstrate acceptable translation of the PRIME models into the ECCS/LOCA evaluation model. Specific testing for other analysis codes is performed to assess the sensitivity of the code update. As discussed in Section 3.6.6 of this SE, an approach has been proposed to assess the sensitivity of the calculations to the model updates in the ECCS/LOCA evaluation model. Therefore, the NRC staff finds that the generic testing requirements are sufficient.

3.6.4 TASC

TASC is applied to several transient and accident analyses. The implementation of PRIME with TASC discussed in Section 3.4.2 of this SE is applicable to ECCS/LOCA analyses.

3.6.5 TRACG

TRACG is applied to several transient and accident analyses. The implementation of PRIME with TRACG discussed in Section 3.4.4 of this SE is applicable to ECCS/LOCA analyses.

3.6.6 10 CFR 50.46 Considerations

According to Supplement 4, the impact of replacing the GSTRM-based models with PRIME-based models in the ECCS/LOCA evaluation model will be treated as a methodology change and will be treated in accordance with the reporting requirements of 10 CFR 50.46 in terms of changes to the calculated PCT. This is acceptable to the NRC staff and consistent with the Commission's regulations.

Supplement 4 states that the impact of the change can be determined by conservatively estimating the change in the PCT as a result of changes in the initial stored energy using the results of SAFER/GESTR sensitivity calculations that are performed as part of the overall methodology to determine the upper bound PCT. The upper bound PCT calculation is performed to demonstrate conservatism in the licensing basis PCT (Reference 1). In the NRC staff review of the SAFER/GESTR methodology, the NRC staff concluded that the initial stored energy was one of several highly important parameters to which the PCT exhibits sensitivity. Therefore, the NRC staff finds that this approach is acceptable to address those specific parameters that are important and impacted by the model updates. Therefore, the NRC staff finds that the proposed approach is consistent with the NRC staff's previous review findings and thereby acceptable.

Additionally, since the PCT sensitivities are calculated for each plant-specific analysis, the proposed approach allows for the unique determination of the PCT impact for each plant referencing the SAFER/GESTR evaluation model.

Supplement 4 further states that when PRIME is fully implemented in the SAFER code that the conservative estimate of the PCT adjustment will no longer be necessary as the calculations will be performed using the approved, updated models. The NRC staff agrees with this assessment.

4 Conclusions

The NRC staff finds that Supplement 4 provides an acceptable process for cascading an approved, updated fuel thermal model into the suite of downstream safety analysis codes. Based on its detailed technical review, the NRC staff has determined that the proposed PRIME implementation plan is sufficient to address Limitation 12 from the NRC staff SE approving the IMLTR. The scope of the model updates is sufficient and addresses all relevant phenomena in the suite of analysis methods. The process is generically acceptable for all operating domains.

The NRC staff reviewed the software testing and implementation to ensure consistency with the requirements of 10 CFR 50, Appendix B, and 10 CFR 50.46 and found that the proposed activities described in Supplement 4 are in accordance with the Commission's regulations.

At the conclusion of the code update and software testing process the NRC staff will audit the final documentation to ensure that the code updates were performed in accordance with the approved process described in Supplement 4. The NRC staff does not intend to review the approach taken to update these codes unless specific deviations are taken from the approved process.

5 References

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4. Letter from GE to NRC, MFN 170-84, "GESTR-MECHANICAL: Fuel Property and Model Revisions," dated December 14, 1984.
5. Letter from NRC to GE, "Acceptance for Referencing of Licensing Topical Report NEDE-24011-P Amendment 7 to Revision 6, 'General Electric Standard Application for Reactor Fuel," dated March 1, 1985. (ADAMS Accession No. ML090760583)
6. LTR NEDC-33173P-A, Revision 1 (IMLTR), "Applicability of GE Methods to Expanded Operating Domains," dated September 2010. (ADAMS Package Accession No. ML102920129)
7. Letter from GEH to NRC, MFN 06-481, "Responses to RAIs 7, 8, 9, 10 and 11 – NEDC-33173P (TAC No. 0277)," dated December 5, 2006. (ADAMS Package Accession No. ML063450448)
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9. LTR NEDC-33256P, "The PRIME Model for Analysis of Fuel Rod Thermal-Mechanical Performance Part 1 – Technical Bases," dated January 2007. (ADAMS Package Accession No. ML070250414)
10. LTR NEDC-33257P, "The PRIME Model for Analysis of Fuel Rod Thermal-Mechanical Performance Part 2 – Qualification," dated January 2007. (ADAMS Package Accession No. ML070250414)
11. LTR NEDC-33258P, "The PRIME Model for Analysis of Fuel Rod Thermal-Mechanical Performance Part 3 – Application Methodology," dated January 2007. (ADAMS Package Accession No. ML070250414)
12. Final Safety Evaluation of NEDC-33256P, NEDC-33257P, and NEDC-33258P, "The PRIME Model for Analysis of Fuel Rod Thermal-Mechanical Performance," dated January 22, 2010. (ADAMS Package Accession No. ML100210284)
13. Letter from GEH to NRC, MFN 09-143, "NEDC-33173P – Implementation of Limitation 12 (TAC No. MD0277)," dated February 27, 2009. (ADAMS Accession No. ML090620309)
14. Letter from GEH to NRC, MFN 09-466, "Implementation of PRIME Models and Data in Downstream Methods, NEDO-33173, Supplement 4, July 2009," dated July 10, 2009. (ADAMS Package Accession No. ML091910492)

15. LTR NEDE-32906P, Supplement 3-A, “Migration to TRACG04/PANAC11 from TRACG02/PANAC10 for TRACG AOO and ATWS Overpressure Transients” (Migration LTR), dated April 2010. (ADAMS Package Accession No. ML110970401)
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26. LTR NEDE-30996P-A, “SAFER Model for Evaluation of Loss-of-Coolant-Accidents for Jet Pump and Non-Jet Pump Plants,” dated October 1987. (ADAMS Package Accession No. ML091210245)
27. LTR NEDC-32950P, Revision 1, “Compilation of Improvements to GENE’s SAFER ECCS-LOCA Evaluation Model,” dated July 2007. (ADAMS Package Accession No. ML072280401)

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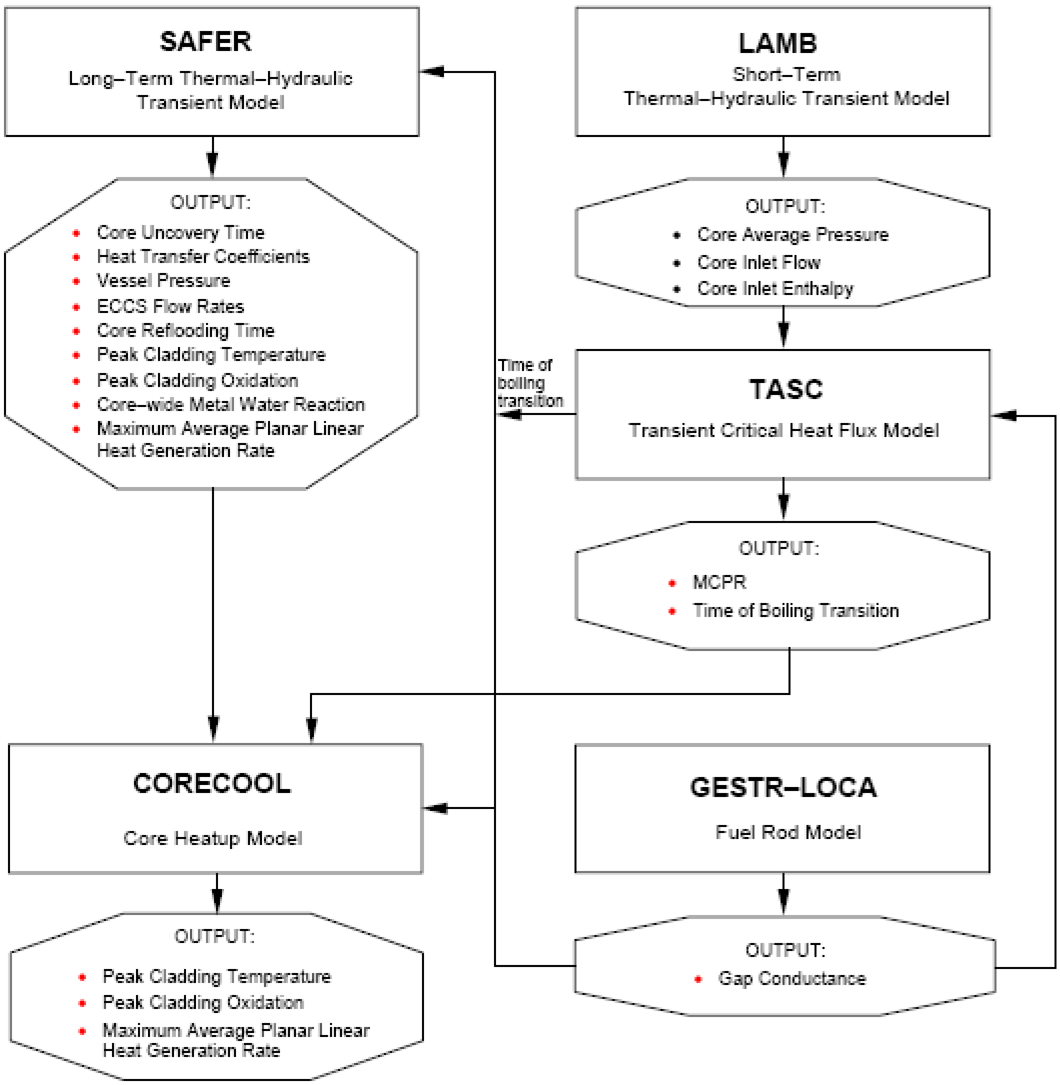

Figure 1: ECCS/LOCA Evaluation Model Process Diagram (Reference 8)

Revision Summary

Revision No.	Section	Content
0		N/A
1	1	Added PRIME Implementation Audit Letter

TABLE OF CONTENTS

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Abstract

The approval of the PRIME thermal-mechanical methodology requires the implementation of consistent fuel property models in codes supporting downstream analyses, such as ECCS/LOCA, stability, and transients . This Licensing Topical Report identifies the scope of these changes, the expected implementation strategy, the minimum validation requirements, and the actions necessary for subsequent review.

1.0 INTRODUCTION

1.1 OVERVIEW

The PRIME[1],[2],[3] model and computer program have been developed to provide predictions of the thermal and mechanical performance of $(U,Gd)O_2$ light water reactor nuclear fuel rods experiencing variable power histories. The PRIME code has been developed from the GESTR-Mechanical (GSTRM)[4] code, primarily to enhance modeling for high exposures and to update modeling for more recent experimental data. Some downstream safety analysis codes incorporate simplified fuel property models that comprise a subset of the type found in PRIME. The two most important of these models, for purposes of downstream safety analyses, are fuel thermal conductivity and fuel pellet to cladding gap conductance. PRIME incorporates a significantly enhanced model for the fuel pellet thermal conductivity. The PRIME pellet-clad gap conductance model formulation has only changed slightly. However, the PRIME code calculated gap conductance will be different from GSTRM due to other models that provide inputs and boundary conditions. This document contains a general plan for incorporation of PRIME-based properties into Engineering Computer Programs (ECPs) and methodologies as described in GESTAR-II-US[5]. The following codes are definitely impacted by this change: SAFER, CORCL, ODYSY, ODYN, and TASC. The generic code names, and specific versions to be updated, are summarized in Table 1-1. Additionally, the steady state nuclear methods will be evaluated for impact as described in Sections 2.2 and 3.3.1.

The changes required for each code are given in more detail in Section 2. The general process for controlling, testing, and releasing updated versions of the ECPs is provided in Section 3.

Table 1-1. Impacted ECPs Using Pre-PRIME Fuel Properties

Methodology	Engineering Computer Program	Reference
Transients	ODYN (ODYNM10A, ODYNV09A)	[6], [7], [8], [9], [10], [11]
	TASC (TASC-03A)	[12], [13], [14]
Stability	ODYSY (ODYSY05A)	[15], [16]
LOCA/ECCS	SAFER (SAFER04A)	[17], [18], [19], [20], [21], [22], [23], [24]
	CORCL (CORCL07A)	[20], [21], [25]
	TASC (TASC-03A)	[14]

1.2 GENERIC IMPLEMENTATION APPROACH

The ECPs to be modified for consistency with PRIME are given in Table 1-1. These are the current production-level ECPs that utilize pre-PRIME fuel properties in the associated calculations. The ECPs primarily incorporate fuel property models for purposes of calculating fuel/cladding temperature and fuel rod surface heat flux. The controlling fuel properties for these calculations are fuel thermal conductivity and fuel-clad gap conductance. Other ECP fuel properties, such as theoretical density and specific heat capacity, will be checked for consistency with PRIME in conjunction with the thermal conductivity model implementation.

These ECPs use a variety of methods for calculating fuel thermal conductivity and gap conductance. The approaches for fuel thermal conductivity vary from a simplified function of temperature to a function of temperature, gadolinia concentration, exposure, and fraction of theoretical density. The approaches for gap conductance vary from a single core-averaged constant value to a dynamic gap conductance calculation, as a function of local linear heat generation rate and exposure and initialized by a GSTRM or PRIME calculation.

The PRIME ECP subroutine that calculates fuel thermal conductivity is a function of temperature, exposure, gadolinia concentration, additive concentration, plutonium concentration, fraction of theoretical density, and fuel melting temperature. This subroutine will be encapsulated with a simplified interface so that ECPs need only provide temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density. The primary adaptation of this model relative to the PRIME code is that instantaneous fuel temperature will be used in any calculation for which PRIME uses history weighted temperatures. Note that a Plutonium concentration of 0.0 % will be assumed for the simplified interface.

The PRIME model for pellet-clad gap conductance requires input from other fuel thermal-mechanical models not typically available in safety analysis ECPs. Gap conductance output from PRIME will be used as input to other ECPs, rather than attempting to replicate the PRIME gap conductance model in each ECP. This output will either be gap conductance values, or files used to initialize ECPs with dynamic gap conductance models (SAFER and TRACG).

Additional inputs will be made available to allow selection of PRIME-based fuel thermal conductivity, and to provide additional arguments to the fuel thermal conductivity calculation. PRIME-based gap conductance will be selected by input of a PRIME-calculated gap conductance or dynamic gap conductance initialization files.

Although the PRIME fuel thermal conductivity formulation is a function of more parameters than previously required, additional detail will not be added to the ECP structure. For example, ODYN utilizes a single one-dimensional (axial) fuel rod. This will not be changed. However, inputs may be provided to allow for axially varying core averaged exposure, gadolinia concentration, and additive concentration. No ECP changes will be made to accommodate PRIME-based gap conductance. This will be handled exclusively through existing inputs.

2.0 METHODOLOGY CHANGES

Each section will contain a brief description of the methodology, current degrees of freedom, and style of implementation for incorporating PRIME thermal properties.

2.1 FUEL THERMAL MECHANICAL

The PRIME03P computer program is used to calculate the thermal/mechanical response of nuclear fuel to time varying power histories. Calculated response parameters include fuel centerline temperature, fission gas release, rod internal pressure, and cladding stress, strain and deformation (including local stress, strain, and ridge height). PRIME can be used for steady state licensing analysis of UO_2 and $(U,Gd)O_2$ fuel with (and without) additive material. Since PRIME contains thermal property formulations of thermal conductivity and gap conductance, consistency with downstream applications is desired. Establishing a licensing basis for fuel additive is not the purpose of this licensing topical report.

2.2 STEADY STATE NUCLEAR METHODS

The "Improved Steady-State Methods"[26], also known as TGBLA06/PANAC11, are used for core design, licensing, and core monitoring. PANAC11 leverages the TGBLA06 Level 2 ECP for preparation of homogenized nodal constants. TGBLA06 is a lattice design computer program for conventional BWRs that have lattices based on 8x8, 9x9, or 10x10 rod matrices. The lattice physics ECP TGBLA06 is not affected by the PRIME thermal property formulation.

The steady-state nuclear methods (PANAC11) require all fission and gamma energy generated in the fuel to be directly deposited in the fuel or moderator. It does not solve the pin conduction equation so there is no direct dependence on thermal-conductivity and/or gap conductance. Instead, it implements a relationship between thermal power and fuel temperature for Doppler feedback. Because Doppler feedback is not a strong reactivity contributor at steady-state conditions in a boiling water reactor environment, there is no strong feedback when changing to PRIME from GSTRM. Currently, the formulation is dependent only on significant changes in product line (8x8, 9x9, and 10x10) and is not dependent on exposure. This lack of dependency on exposure is not directly associated with the thermal conductivity formulation but a reasonable assumption for steady-state applications.

However, an investigation on the difference between PRIME based heat flux tables and the existing GSTRM based heat flux tables will be completed. If the PRIME relationship is statistically significantly different, the PANAC11 input structure will be modified and the fuel temperature calculation will allow usage of this new structure as an option. In the event that changes to PANAC11 are required, codes downstream of PANAC11 may need modification, depending on the particular form of the changes to PANAC11.

PANAC11 retrieves some thermal-hydraulic information from a steady-state ECP denoted as ISCOR. ISCOR is not directly dependent on thermal-mechanical properties since the heat flux on the rods is a direct input to the steady-state thermal-hydraulics simulation.

2.3 TRANSIENT ANALYSIS

Various plant transients are analyzed for purposes of plant and core licensing. The transient analyses of various anticipated operational occurrences are used for reload licensing and operating limit determination. In particular, system pressure, reactor vessel level, fuel minimum critical power ratio (MCPR), and fuel thermal-mechanical response may be evaluated for acceptability. For the present purposes, the anticipated transients without scram are also included with the transient analyses since the same ECPs are impacted. The rod withdrawal error and loss of feedwater heating events are normally analyzed with PANACEA (see Section 2.2). The bulk of transient events are analyzed with ODYN using one-dimensional kinetics. When ODYN is utilized, the nuclear data is extracted and collapsed from PANACEA by a buffer code and the MCPR post-processing is performed by TASC.

2.3.1 ODYN

The ODYN ECPs use a single core average gap conductance value, with optional axial multipliers. This will continue to be the case, although the source of these inputs will be based on PRIME.

The current fuel thermal conductivity formulation in ODYN is a built-in table of thermal conductivity as a function of temperature. The only user input is a global multiplier on fuel/clad thermal conductivity. ODYN will be modified with a switch to select the PRIME-based fuel thermal conductivity. With this option selected, ODYN will use the PRIME-based thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density. These additional arguments will either be provided from PANACEA through the buffer code, supplied as default values, or supplied by the user.

2.3.2 TASC

The TASC ECP has multiple gap conductance options. However, constant, axially-varying values are typically input. This input may change to be consistent with PRIME.

The current TASC fuel thermal conductivity formulation is also a function only of temperature, although the table can be overlayed by the user. TASC will be modified to employ a similar strategy as ODYN for the PRIME-based fuel thermal conductivity calculation.

2.4 STABILITY

Core and channel decay ratio calculations are performed to ensure that the fuel is as stable as previously licensed GE fuel designs, or to revise the stability exclusion region.

Additionally, CPR response calculations are performed to demonstrate that the generic DIVOM curve (Delta CPR over Initial CPR Vs. Oscillation Magnitude) is applicable, or to generate a new curve. Finally, stability events are simulated to confirm the adequacy of detect and suppress solutions. Frequency-domain stability calculations are performed with the ODYSY ECP and time-domain stability calculations are performed with TRACG (see Section 2.6).

The ODYSY ECP allows the input of gap conductance for up to each axial level of each channel group. Typically, however, a core average value with simple power dependence is utilized. Only the supplied input will change for the PRIME-based gap conductance implementation.

Currently, ODYSY can calculate the fuel thermal conductivity as a function of temperature and gadolinia concentration. ODYSY will be modified with a switch to select the PRIME-based fuel thermal conductivity. With this option selected, ODYSY will use the PRIME-based thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density. These additional arguments will either be provided from PANACEA through the buffer code, supplied as default values, or supplied by the user.

2.5 LOCA/ECCS PERFORMANCE

The SAFER/GESTR methodology is currently used to determine the effects of the loss–of–coolant accident (LOCA) in accordance with the requirements of 10CFR50.46 and Appendix K. This methodology utilizes ECCS evaluation models along with a realistic application approach to calculate a licensing peak clad temperature (PCT) with margin substantiated by statistical considerations. This methodology involves the SAFER, CORCL, and TASC ECPs (see Section 2.3.2 regarding TASC).

2.5.1 SAFER

The SAFER ECP has the option to use input gap conductance values for each heated node of each rod group, or use the built-in gap conductance model (constant or dynamic). Normally, the dynamic gap conductance model is used, requiring the input of initialization data from GESTR or PRIME. Only the supplied input will change for the PRIME-based gap conductance implementation.

SAFER currently allows for the input of fuel thermal conductivity as a function of temperature. SAFER will be modified with an option to select the PRIME-based fuel thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density.

2.5.2 CORCL

The CORCL ECP has similar gap conductance options as SAFER. Normally, the required information is passed to CORCL from SAFER via interface files. No code changes will be made to CORCL to implement the PRIME-based gap conductance.

CORCL currently allows for fuel thermal conductivity as a function of temperature to be passed from SAFER, based on an internal model, or input by the user. CORCL will be modified with an option to select the PRIME-based fuel thermal conductivity as a function of temperature, exposure, gadolinia concentration, additive concentration, and fraction of theoretical density.

2.6 TRACG

The TRACG04A,P ECP may be used for multiple applications, including transients[27],[28],[29],[30], stability[31],[32], and, in the future, ECCS/LOCA (TRACG04 has been used for ESBWR LOCA calculations[33], with an application for other plants under development). TRACG is discussed separately since it has been recently extensively reviewed, and will not be modified for the PRIME implementation.

TRACG has the option to use input gap conductance values for each heated node of each rod group of each CHAN component, or use the built-in gap conductance model (constant or dynamic). Normally, the dynamic gap conductance model is used with TRACG, requiring the input of initialization data from GESTR or PRIME. Only the supplied input will change for the PRIME-based gap conductance implementation.

The current TRACG default fuel thermal conductivity formulation is essentially the PRIME-based formulation without additive. In particular, the thermal conductivity is a function of temperature, exposure, gadolinia concentration, and fraction of theoretical density. With 3D kinetics, the exposures are automatically set to the values from the PANAC wrapup used for the steady state calculation. Gadolinia concentration currently defaults to 0.0 and fraction of theoretical density currently defaults to 0.97, although these values may be changed by input.

3.0 IMPLEMENTATION AND TESTING

3.1 SOFTWARE QUALITY ASSURANCE PLAN

GEH follows a quality assurance (QA) plan for ECPs that is compliant with Appendix B of Title 10 Part 50 of the Code of Federal Regulations (10 CFR 50). In accordance with this procedure, the code changes described within this document will be classified as a maintenance activity since the original constructions based upon GSTRM formulations and application will still be available. The software test plan and software test report will be constructed to test all changes made to the ECPs as well as sufficient testing to provide confidence that other models or functionality of the code have not been changed.

3.2 GENERIC REQUIREMENTS

For all of the modified ECPs, the PRIME-based properties will be added as an option, while the current formulation will be retained for backward compatibility and sensitivity studies. For each affected code, the PRIME property formulation will be tested via unit testing or code review to confirm that the correct properties have been implemented. The acceptance criteria for this examination is that the formulation reproduces the PRIME properties for the expected range of application. Additionally, a small number of simulations using the current properties and new PRIME property inputs will be run as both a regression test to the prior code version and a sensitivity confirmation. The sensitivity test is intended to be representative, such that a comprehensive requalification is deemed unnecessary.

Following or in parallel to this testing of the ECP, implementation testing within each functional area will be conducted. The purpose of this testing is to establish the following elements of impact:

- Process changes necessary to provide the additional inputs (e.g. exposure) to exercise the PRIME thermal property formulations.
- Comparison of the application process using PRIME properties versus existing properties.
- Comparison of the application process sensitivity compared to the application sensitivity based on TRACG[34] (see additional considerations in Section 3.3).
- Determination of the significance of the changes considering the process for including uncertainties in the application methodology (see additional considerations in Section 3.3).

These elements of impact will be subsequently examined by a process of independent verification or design review to recommend the final application process.

3.3 SPECIFIC REQUIREMENTS BY METHODOLOGY

3.3.1 Steady State Nuclear Methods

PRIME will be used to prepare new heat flux tables for comparison with existing GSTRM based heat flux tables. Examination of any additional dependencies (e.g. exposure) will be a part of this investigation.

If the PRIME relationships demonstrate a statistically significant bias relative to the GSTRM relationships, a representative plant fully loaded with GNF fuel will be chosen for exposure accounting comparison of hot and cold eigenvalues and TIPs. Changing the Doppler relationship may lead to different exposure accrual so a burn-in period of one or more cycles will be required before a consistent analysis can be made.

3.3.2 Transient Analysis

Representative analyses, with current and PRIME-based fuel properties, will be performed with ODYN and TASC in order to assess the impact and determine the need for further testing. In particular, the limiting reload licensing transients for a single plant with ODYNM10 and another plant with ODNYV09 will be performed. Note that the MCPR transients will test the PRIME-based fuel properties in TASC. Additionally, an ATWS simulation will be performed with an ODYNM10 plant and an ODYNV09 plant. The peak clad temperature evaluation portion of the ATWS simulations provides a test of TASC for this application.

3.3.3 Stability

Since ODYSY is a frequency domain code, comparisons and determination of the significance of the changes will be based on decay ratio evaluations. Representative analyses, with current and PRIME-based fuel properties, will be performed with ODYSY in order to assess the impact and determine the need for further testing. In particular, the limiting cases in representative reload licensing stability analyses for one Option I-D, one Option II, one Option-III and one DSS-CD plant (or application) will be performed with ODYSY05.

3.3.4 LOCA/ECCS Performance

The impact of using PRIME properties instead of GSTRM properties will be treated as a change in the approved methodology, per the reporting requirements of 10CFR50.46. The impact of this change can be conservatively estimated from the stored energy sensitivities that are carried out as a part of the Upper Bound PCT and oxide thickness calculations. These calculations in the SAFER/GESTR methodology adjust the nominal PCT to account for modeling and plant variable biases and uncertainties.

In some cases, if the conservative estimate results in a PCT that exceeds the regulatory limit, more detailed calculations will be performed to take into account effects such as exposure dependence, or plant-specific inputs. When PRIME is implemented in the SAFER ECP, this conservative estimate will no longer be necessary. The calculations will be based on the updated models.

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