ENCLOSURE 2

MFN 14-017

NEDO-31959, "Fuel Rod Thermal-Mechanical Analysis Methodology (GSTRM)," April 1991

Non-Proprietary Information– Class I (Public)

IMPORTANT NOTICE

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GE Nuclear Energy

175 Curtner Avenue
San Jose, CA 95125

NEDO-31959
Class I
April 1991

GE NUCLEAR ENERGY

FUEL ROD THERMAL-MECHANICAL ANALYSIS METHODOLOGY (GSTRM)

NOTICE

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1. Summary

This report describes the GSTRM model for the best-estimate prediction of nuclear reactor fuel rod thermal-mechanical performance. The model incorporates the effects of fuel cladding thermal expansion, fuel cladding creep, and fuel irradiation swelling, densification, relocation, and fission gas release as they affect pellet-cladding thermal conductance, fuel rod internal pressure, and cladding deformation.

2. Model Description

The fuel rod thermal-mechanical performance model predicts fuel rod thermal-mechanical performance for variable operating power histories. The fuel rod operating power history is defined by the input of the irradiation conditions for a number of time (or exposure) steps.

The model performs a combined incremental and iterative solution by internally dividing the input power-time steps into a number of smaller power increments taken in zero time, and time increments taken at a constant power. The time increments are taken such as to ensure a stable mechanical solution. The nature of the fuel and cladding creep behavior requires small time steps after power changes when the creep rates are high but permits larger time steps later in the analysis history when the creep rates are low. The time increments employed within an input time step have been parametrically derived to ensure accurate results over the expected range of stress-strain conditions and material properties of interest in the analysis of fuel rod operation.

For a single time increment:

> First, the gas composition within the fuel rod is determined considering the initial fill gas and any gases released from the fuel during its irradiation history up to the present time increment. An initial estimate of the fuel rod internal gas pressure is calculated based on the gas inventory, initial fuel rod void volume, and an assumed gas temperature.
>
> Next, the "axial nodes" loop is entered, wherein cladding temperatures are calculated from internally calculated film coefficients (including the effects of crud deposition and oxide formation on the cladding surface) and cladding thermal conductivity. This is followed by calculations to determine the extent of (1) fuel irradiation-induced densification, causing pellet radial shrinkage away from the cladding; (2) fuel irradiation swelling, resulting in a positive expansion of the pellet; and (3) fuel relocation, resulting in radial displacement of the cracked pellet sections toward the cladding, reducing the diametral gap. With an assumption for the hot fuel-cladding diametral gap, the "gap conductance" loop is entered where an iterative procedure is employed to calculate the pellet surface temperature using a modified version of the gap heat transfer coefficient model of Ross and Stoute.

After a converged pellet surface temperature and gap conductance are obtained for the assumed hot diametral gap, the fuel radial temperature distribution is calculated, allowing determination of the fuel thermal expansion.

At this point, the mechanical interaction calculations begin. The radial thermal and mechanical calculations assume the idealization of concentrically located pellet and cladding. The effect of pellet eccentricity and/or tilting is, however, included through the component axial slip model. The axial slip algorithm predicts the relative fuel-cladding axial strain as a function of fuel rod geometry, axial position in the fuel column, and hot diametral fuel-cladding gap. With this estimate of relative fuel-cladding axial strain, an initial estimate of the total fuel and cladding axial strain increment is made.

The simplified finite element radial mechanical analysis begins by separating the fuel rod into cladding ring elements, fuel cladding gap elements, and equal-thickness fuel ring elements. The cladding rings provide the capability to analyze bimetallic cladding consisting of an outer layer of Zircaloy and an inner layer of Zirconium (barrier cladding). The initial strain increments of each ring element due to swelling, densification, relocation, and thermal expansion are then determined. Depending upon whether the present analysis increment is a power step during an instantaneous ramp or a time step during a constant power hold, either fuel and cladding plasticity calculations or fuel-cladding creep and pellet hot pressing calculations are performed. The resultant plastic or creep strain increments are then used together with the crack front locations determined from the previous time step, in the determination of the fuel rod element load vectors. Determination and assembly of the fuel and cladding element stiffness matrices (involving an assumption on the state of the fuel-cladding gap, i.e., open or closed), together with assembly of the element load vectors then allows determination of the fuel and cladding ring element total strain increments.

The fuel and cladding stress components and axial loads are then determined. If the calculated fuel and cladding axial loads are not equal, another estimate of the fuel and cladding axial total strain increment is made and the calculations repeated until load equilibrium is established. At this point, the calculated fuel and cladding displacements are employed to update the fuel-cladding gap closure. If a converged thermal solution is also present at this time, the locations of the fuel radial and transverse crack fronts are updated. If the thermal calculation is not converged, an iterative procedure is performed to ensure consistency between the hot fuel-cladding diarnetral gap calculated by the mechanical model and the hot gap employed in the gap conductance calculation. When convergence is obtained, the amount of gaseous fission products released from the axial node is determined.

3. MODEL QUALIFICATION

The model's predictive capability has been demonstrated relative to (1) fuel temperatures, (2) fuel rod permanent axial and diametral deformations, (3) fission gas release from the fuel to the fuel rod void volume, and (4) hot fuel rod operating internal pressure.

ENCLOSURE 3

MFN 14-017

Affidavit

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, Jerald G. Head, state as follows:

(1) I am the Senior Vice President, Regulatory Affairs of Licensing Regulatory Affairs of GE-Hitachi Nuclear Energy Americas LLC (GEH), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in NEDE-31959P, "Fuel Rod Thermal-Mechanical Analysis Methodology (GSTRM)," April 1991. This is a legacy document which is considered proprietary in its entirety. The header of each page in this enclosure carries the notation "GEH Proprietary Information – Class III (Confidential) {3}." The notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding and determination of proprietary information of which it is the owner or licensee, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act (FOIA), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for trade secrets (Exemption 4). The material for which exemption from disclosure is here sought also qualifies under the narrower definition of trade secret, within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975 F2d 871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704 F2d 1280 (DC Cir. 1983).

(4) The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a and (4)b. Some examples of categories of information that fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH's competitors without license from GEH constitutes a competitive economic advantage over GEH and/or other companies. In this case, the information sought to be withheld is business-confidential information related to the GEH organization.

b. Information that, if used by a competitor, would reduce their expenditure of resources or improve their competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product. In this case, the information sought to be withheld is business-confidential information related to the GEH organization.

c. Information that reveals aspects of past, present, or future GEH customer-funded development plans and programs, that may include potential products of GEH.

d. Information that discloses trade secret and/or potentially patentable subject matter for which it may be desirable to obtain patent protection.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to the NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, not been disclosed publicly, and not been made available in public sources. All disclosures to third parties, including any required transmittals to the NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary and/or confidentiality agreements that provide for maintaining the information in confidence. The initial designation of this information as proprietary information and the subsequent steps taken to prevent its unauthorized disclosure are as set forth in the following paragraphs (6) and (7).

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, who is the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or who is the person most likely to be subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited to a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist, or other equivalent authority for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary and/or confidentiality agreements. In this case, the information sought to be withheld is business-confidential information related to the GEH organization.

(8) The information identified in paragraph (2) above is classified as proprietary because it communicates sensitive business information regarding GEH Management and Oversight organization structures and philosophy. In this case, the information sought to be withheld is business-confidential information related to the GEH organization.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. In this case, the information sought to be withheld is business-confidential information related to the GEH organization.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing and obtaining these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 29th day of March 2014.

Jerald G. Head
Senior Vice President Regulatory Affairs
GE-Hitachi Nuclear Energy Americas LLC