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**Proprietary Notice**

This letter transmits proprietary information in accordance with 10CFR2.390. Upon removal of Enclosure 1, the balance of the letter may be considered non-proprietary.

January 4, 2008
MFN 07-040 Supplement 1

52-010

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

**Subject:** **Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M – Supplement 1**

The NRC staff requested that GE-Hitachi Nuclear Energy (GEH) evaluate the potential non-conservatism in the GE Thermal-Mechanical Methodology, GESTR-M, identified in the ESBWR design certification review in accordance with the provisions of 10CFR Part 21. The staff was concerned that qualification of GESTR-M against high exposure fuel data could indicate that GESTR-M under-predicts fuel centerline temperature.

GEH completed an extensive evaluation and concluded that GESTR-M and its associated statistical methodology, in conjunction with the exposure dependent Linear Heat Generate Rate (LHGR) limit, was adequate for fuel licensing and design calculations within its qualification domain and therefore did not constitute a reportable condition under 10CFR21. A summary of that evaluation was provided on January 21, 2007 in letter number MFN 07-040.

Based upon review of MFN letter 07-040 the NRC concluded that the GESTR-M model and associated methodology are adequate to confirm compliance with fuel temperature and cladding strain SAFDLs but requested additional quantification of the conservatism in the calculation to confirm compliance with the rod internal pressure SAFDL. This quantification is provided by this supplement. Based upon the quantification, GEH concludes that the GESTR-M model and application methodology are sufficiently conservative to address NRC concerns regarding GESTR-M and its associated application methodology to confirm compliance with the fuel rod internal pressure SAFDL. Thus GEH also concludes this additional quantification further supports the conclusion stated in the initial transmittal (MFN 07-040), namely that GESTR-M and its associated statistical methodology, in conjunction with the exposure dependent Linear Heat Generation Rate (LHGR) limit, is adequate for fuel licensing and design calculations within its qualified domain, and that application of GESTR-M and its associated methodology does not constitute a reportable condition under 10CFR21.

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Please note that Enclosure 1 contains proprietary information of the type that GEH maintains in confidence and withholds from public disclosure. The information has been handled and classified as proprietary to GEH as indicated in its affidavit. The affidavit contained in Enclosure 3 identifies that the information contained in Enclosure 1 has been handled and classified as proprietary to GEH. GEH hereby requests that the information in Enclosure 1 be withheld from public disclosure in accordance with the provisions of 10CFR2.390 and 9.17.

Enclosure 1 is the proprietary version of the supplement and Enclosure 2 is the non-proprietary version. Enclosure 3 contains the affidavit.

If you have any questions on this information, please call me at (910) 602-4491.

Sincerely,

Dale E. Porter
Safety Evaluation Program Manager

cc: S. B. Alexander (NRC-NRR/DISP/PSIM) Mail Stop 6 F2
M. C. Honcharik (NRR/DPR/PSPB) Mail Stop O-7D11
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G. B. Stramback (GEH)
PRC File
DRF No. 0000-0063-5844

Enclosures:
1. Assessment of Conservatism in Fuel Rod Internal Pressure Design Ratio - GEH Proprietary Information (CD ROM)
2. Assessment of Conservatism in Fuel Rod Internal Pressure Design Ratio - Non-Proprietary Information)
3. Affidavit

ENCLOSURE 1 (CD ROM)

MFN 07-040 Supplement 1

# Assessment of Conservatism in Fuel Rod Internal Pressure Design Ratio

GEH Proprietary Information

**PROPRIETARY INFORMATION NOTICE**

This enclosure contains proprietary information of the GE-Hitachi Nuclear Energy (GEH) and is furnished in confidence solely for the purpose(s) stated in the transmittal letter. No other use, direct or indirect, of the document or the information it contains is authorized. Furnishing this enclosure does not convey any license, express or implied, to use any patented invention or, except as specified above, any proprietary information of GEH disclosed herein or any right to publish or make copies of the enclosure without prior written permission of GEH.

The header of each page in this enclosure carries the notation "GNF Proprietary Information." The GNF proprietary information is identified by a dotted underline inside double square brackets. [[This sentence is an example.[3]]] Figures and large equation objects containing proprietary information are identified with double square brackets before and after the object. In each case, the superscript notation [3] refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

ENCLOSURE 2

MFN 07-040 Supplement 1

# Assessment of Conservatism in Fuel Rod Internal Pressure Design Ratio

Non-Proprietary Version

**IMPORTANT NOTICE**

This is a non-proprietary version of Enclosure 1 to MFN 07-040 Supplement 1, which has the proprietary information removed. Portions of Enclosure 1 that have been removed are indicated by an open and closed bracket as shown here [[ ]].

ENCLOSURE 3

MFN 07-040 Supplement 1

Affidavit

# GE-Hitachi Nuclear Energy Americas LLC

## AFFIDAVIT

**I, James F. Harrison,** state as follows:

(1) I am Vice President, Fuel Licensing, Regulatory Affairs, GE-Hitachi Nuclear Energy Americas LLC ("GEH"), 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 Enclosure 1 of GEH letter, MFN 07-040 Supplement 1, Dale E. Porter (GEH) to Document Control Desk (USNRC), Subject: *Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M – Supplement 1*, dated January 4, 2008. GEH proprietary text in Enclosure 1, which is entitled "Assessment of Conservatism in Fuel Rod Internal Pressure Design Ratio", is identified by a dotted underline inside double square brackets [[This sentence is an example.{3}]]. Figures and large equation objects containing GEH proprietary information are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding 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 qualify 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, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which 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 other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to 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, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties, including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

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

(8) The information identified in paragraph (2), above, is classified as proprietary because it contains the detailed results including the results, qualification data, and methodology for application of GESTR-M to the design and licensing of GE BWRs. This GESTR-M code has been developed by GEH, at a total cost in excess of three million dollars. The reporting, evaluation and interpretations of the results, as they relate to the BWR, was achieved at a significant cost to GEH.

The development of the methodology along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(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. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

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 4th day of January 2008.

James F. Harrison
Vice President, Fuel Licensing,
Regulatory Affairs
GE-Hitachi Nuclear Energy Americas LLC

**Supplement to MFN 07-040 (Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M)**
**Assessment of Conservatism in Fuel Rod Internal Pressure Design Ratio**

## 1.0 Introduction

Fuel rod thermal-mechanical design and licensing analyses for GE fuel designs are performed using the GESTR-M code and associated application methodology. The licensing criterion applied to rod internal pressure is to assure with [[

]]
The criterion is applied to assure that cladding liftoff and the adverse feedback of liftoff on fuel temperature, fission gas release and rod internal pressure are precluded.

[[

]]

[[

]] This assessment quantifies conservatisms in the calculated nominal critical pressure and in the calculated design ratio. [[

]]

This assessment is based upon the GE14 full length $UO_2$ rod, [[

]] However, the conclusion is applicable to other GE fuel designs as well. Specifically, as noted in the [[
]]

[[

]] Beyond this exposure, the increase in internal pressure due to the increase in released fission gases is offset by the reduction in LHGR limit beyond the second knee in the LHGR limit curve and the corresponding reduction on cladding temperature and fast flux, which result in reduced cladding creep rate and increased critical pressure.

[[

]] In this assessment, GNF will show that sufficient conservatisms exist in the calculation of the critical pressure and critical pressure uncertainty. [[

]]

## 2.0 Analyses

### 2.1 Relation for Critical Pressure

To assess the conservatisms and nonconservatisms in the critical pressure and DR calculations, an expression for critical pressure is derived by [[

]] The result is

where

[[

]]

To demonstrate application of this expression, the nominal critical pressure for the GE14 $UO_2$ rod at the second knee of the LHGR limit curve (as noted previously this is the approximate point of maximum design ratio) is calculated as follows.

Nominal values of $P_o$, $r_p$, $r_i$ (neglecting the barrier) and $r_o$ are

[[

]]

At the second knee of the LHGR limit curve the value of LHGR is

[[ ]]

and the operating time (under liftoff conditions) is assumed to be [[

]]

From the GE14 nominal T-M licensing analysis, the average cladding temperature at the second knee is

[[

]]

Substituting these values into the expression for $P_c$ yields

[[ ]]

## 2.2 Potential Conservatisms/Nonconservatisms in $P_c$

From the derivation of the relation for critical pressure in Section 2.1, [[

]] For this assessment, this nonconservatism is treated as a nonconservatism in the calculation of the critical pressure. The magnitude of each of these potential conservatisms and nonconservatisms is assessed and quantified below.

**Nominal Swelling Rate**

As noted above, GNF [[

]] The revised rate is consistent with rates report in the open literature, as summarized in Attachment 1. These observations support the use of the higher rate in the calculation of critical pressure for cladding liftoff.

**Cladding Creep Rate**

The relation for $P_c$ derived above assumes the same cladding creep relation used in the GESTR-M code. [[

]]

Comparison of the GESTR-M low stress creep relation with the database upon which the relation is based is presented in Attachment 2. Also shown in Attachment 2 are comparisons of the GESTR-M creep relation to data, which has become available since the development of the GESTR-M relation.

For assessment of the potential conservatism or nonconservatism in the use of the GESTR-M creep relation in the critical pressure calculation, the data presented in Attachment 2 is summarized in Figure 2-6 of Attachment 2. In this figure, the data is normalized to the conditions assumed for the nominal critical pressure calculation above using the temperature and flux dependencies in the GESTR-M relation and compared to the GESTR-M relation. For information, the PRIME relation and the Limback and Andersson relation (ASTM STP 1295), which is widely used in the nuclear industry, are also shown. From Figure 2-6, it is observed that the GESTR-M relation generally agrees with the data and with the Limback and Andersson relation. [[

]]

On the basis of Figure 2-6, it is concluded that the GESTR-M creep relation is adequate for the critical pressure calculation. [[

]]

**Calculation of Cladding Stress**

The GE14E fuel design includes barrier cladding consisting of a recrystallized annealed Zircaloy-2 tube with a zirconium liner (barrier) on the inner surface. In the calculation of $P_c$, [[

]]

Use of Ideal Gas Law

[[

]]

## 2.3 Total Conservatism in Calculated Critical Pressure

The impacts of the conservatisms and nonconservatisms discussed in Section 2.2 can be quantified using the relation for critical pressure in Section 2.1. [[

]]

Thus, on the basis of the items identified and assessed in this analysis, the conservatism in the calculated critical pressure for cladding liftoff is [[ ]]

## 2.4 Total Conservatism in Calculated Critical Pressure Uncertainty

The standard deviation in the calculated critical pressure is calculated by perturbing parameters used in the calculation of $P_c$ on the basis of characterized uncertainties to determine the sensitivity of $P_c$ to these parameters. The results are then combined statistically using the error propagation method to determine $\sigma_{pc}$.

As noted in Section 1.0, [[

]] This assumed uncertainty is consistent with the swelling data in Attachment 1.

[[

]]

[[

]] These results indicate a net conservatism of [[ ]] psia in the currently calculated critical pressure uncertainty.

### 2.5 Impact of Higher Cladding Creep Rate

As noted in Section 2.2, [[

]]

The results summarized in Sections 2.3 and 2.4 reflect this assumption.

[[

]] These assumptions are considered conservative for the following reasons. First, there is no creep data for recrystallized annealed Zircaloy in the upper end of the stress range corresponding to liftoff. Second, [[

]]

To assess the conservatisms and nonconservatisms in the critical pressure and critical pressure uncertainty by using PRIME creep rate an expression of critical pressure is derived as

[[ ]]

where, $P_c$ is in ksia.

Repeating the calculations in Section 2.2 and 2.4 with these revised assumptions, [[

]]

## 3.0 Summary/Conclusion

In this analysis, potential conservatisms and nonconservatisms in the calculation of the nominal critical pressure $P_c$ and the critical pressure uncertainty $\sigma_{pc}$ are quantified for the GE14 full length $UO_2$ fuel rod design. [[

]]

The probability of liftoff is determined by the internal pressure design ratio, which combines the distributions of internal pressure and critical pressure statistically such that [[

]] These results are summarized in Table 1b – 1d.

A similar conclusion applies to the results in Section 2.5. These results indicate that even [[

]] These results are summarized in Table 1e – 1g.

Table 1
Results of Critical Pressure Assessment

Table 1a: Summary of Fuel Swelling Data

| | | | | |
|---|---|---|---|---|
| [[ | | | | |
| | | | | |
| | | | | ]] |

Table 1b: Conservatism in GESTR-M Critical Pressure with GESTR-M Creep Correlation

| Parameters | Conservatism, psia |
|---|---|
| [[ | |
| | |
| | |
| | ]] |

Table 1c: Conservatism in GESTR-M Critical Pressure Uncertainty wtih GESTR-M Creep Correlation

| Parameters | Uncertainty, % (1-sigma) | Conservatism, psia |
|---|---|---|
| [[ | | |
| | | |
| | | ]] |

[[

]]

[[

]]

Table 1d: Upper95 Design Ratio (Inputs from Table 1b & 1c are used)

[[

]]

Table 1e: Conservatism in GESTR-M Critical Pressure with PRIME Creep Correlation

| Parameters | Conservatism, psia |
|---|---|
| [[ | |
| | |
| | |
| | |
| | |
| | |

]]

Table 1f: Conservatism in GESTR-M Critical Pressure Uncertainty wtih PRIME Creep Correlation

| Parameters | Uncertainty, % (1-sigma) | Conservatism, psia |
|---|---|---|
| [[ | | |
| | | |
| | | |

]]

[[

]]

Table 1g: Upper95 Design Ratio (Inputs from Table 1e & 1f are used)

[[

]]

On the basis of the results above, GNF concludes that the design ratio calculated by the GESTR-M code and associated critical pressure methodology is adequate to confirm compliance with the requirement to demonstrate with at [[ ]] Although this analysis is performed for GE14, as noted in Section 1.0, the conclusion is generic and applicable to other GE fuel designs, including the GE14E fuel design.

**Attachment 1 - Assessment of Swelling Data**

[[

]]

Figure 1-1: GESTR-M Fuel Swelling Model (fuel column length change measurements)

[[

]]

Figure 1-2: GESTR-M Fuel Swelling Model (fuel density measurements)

[[

]]

Figure 1-3: New GNF Measured Pellet Density Data from Three Different NUPEC Programs for 8x8 BWR Fuel.

[[

]]

Figure 1-4: New GNF Swelling Data Derived from Pellet Density Measurements from Three Different NUPEC programs for 8x8 BWR Fuel.

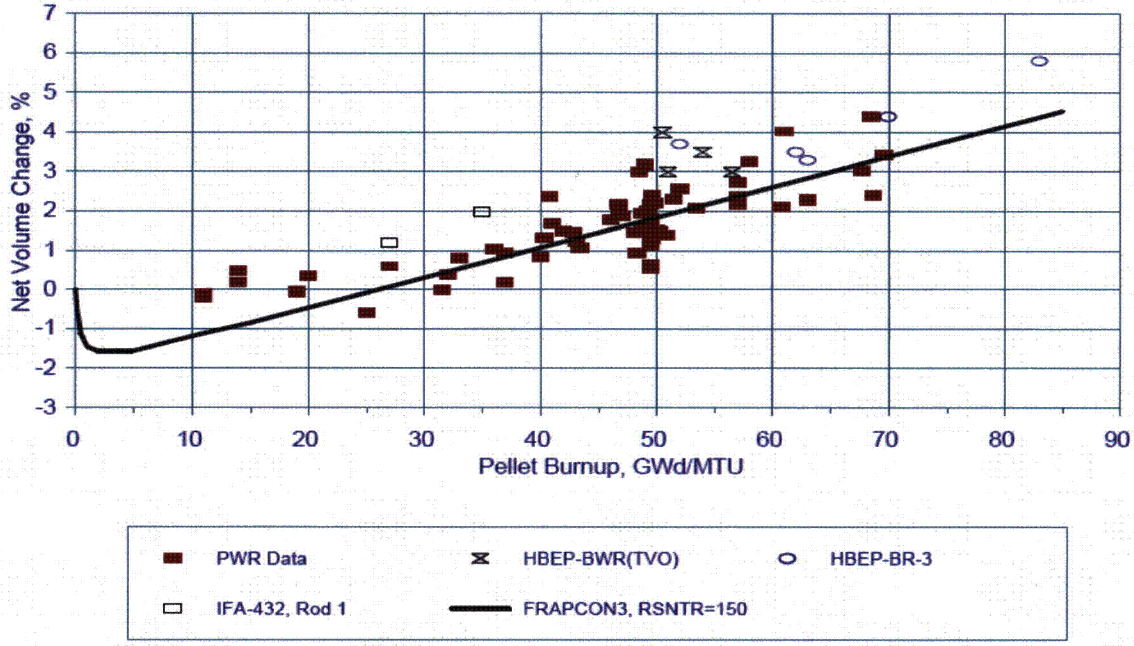


Figure 1-5: FRAPCON3 Fuel Swelling Model[1-1]

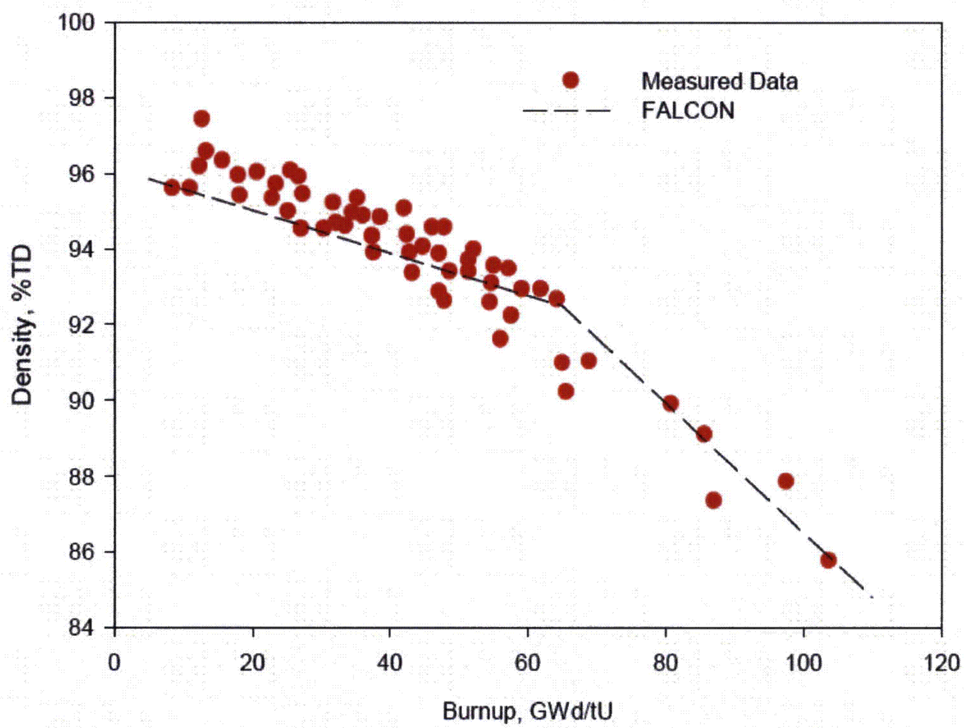


Figure 1-6: FALCON MOD01 Fuel Swelling Model[1-2]

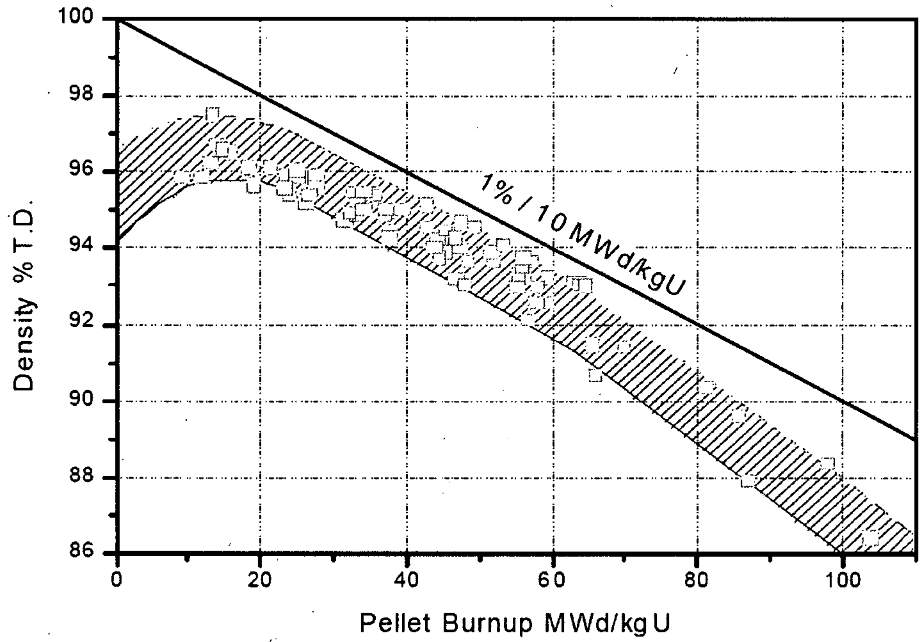


Figure 1-7: Density of Fuel Pellet as a Function of Pellet Burnup[1-3]

***References:***

[1-1] Lanning et. Al., "FRAPCON-3: Modifications to Fuel Rod Material Properties and Performance Models for High-Burnup Application", NUREG/CR-6534, October 1997.

[1-2] Lyon et. Al., "Capabilities of the FALCON Steady State and Transient Fuel Performance Code" Paper 1090, 2004 LWR Fuel Performance Mtg, Orlando, Florida

[1-3] Manzel R., "High Burnup Fuel Microstructure and its Effect on Fuel Rod Performance," 2000 Light Water Reactor Conference, Park City, Utah.

## Attachment 2 - Assessment of Cladding Creep Data

[[

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Figure 2-1: Comparison of GESTR-M Creep Model with Open Literature Data[2-1]

[[

]]

Figure 2-2: Comparison of GESTR-M Creep Model with Open Literature Data[2-2]

[[

]]

Figure 2-3: Comparison of GESTR-M Creep Model with Open Literature Data[2-3]

[[

]]

Figure 2-4: Summary of GESTR-M Creep Model Predictions (temperature 288-350°C)

[[

]]

Figure 2-5: Comparison of GESTR-M Creep Model with Open Literature Data[2-4]

[[

]]

Figure 2-6: Uncertainty in GESTR-M Creep Rate

*References:*

[2-1] Reference: Ficara, PL et al., "Zircaloy-2 In-Pile Creep; Predicted-Measured Values Comparison", Enlarged Halden Program Meeting, Loen, Norway, June 1978.

[2-2] Rieger , GF and RE Blood, RE, "Creep of Zirconium alloys irradiated in the Big Rock Point BWR", CME Transmittal No. 78-212-0009, Rev. 1, February 27, 1978.

[2-3] "Hot Cell Examination of Creep Collapse and Irradiation Growth Specimens, End of Cycle 2" RP-711-1 EPRI/1 B and W Cooperative Program. Key Phase Report. No. 4, August 1979. LRC 4733-7, Babcock and Wilcox.

[2-4] Gilbon et. Al., "Irradiation Creep and Growth Behavior, and Microstructural Evaluation of Advanced Zr-Base Alloys," ASTM STP 1354, 2000.

## Attachment 3 - Impact of van der Waals Equation of State

At high burnup, the gas in the fuel rod is a mixture of helium fill gas and released fission gases, primarily helium, xenon and krypton. Critical temperature and pressure for these gases are given in Table 3-1 (from Marks, Table 4.2.19).

Table 3-1: Critical temperature and pressure for the initial fill gas and released fission gases

| Gas | Tc<br>Critcal Temperarure (K) | Pc<br>Critical Pressure (bar) |
|---|---|---|
| Helium | 5.2 | 2.3 |
| Xenon | 290.0 | 58.7 |
| Krypton | 209.4 | 55.0 |

For high burnup, a typical molar composition is

[[

]]

Then for the gas mixture the critical temperature and pressure are calculated following Kay as

[[

]]

(from Marks, Figure 4.1.3).

To obtain an even more conservative value of Z, the assumed pressure is increased and the assumed temperature is decreased. [[

]]

(from Marks, Figure 4.1.3).

**Attachment 4- Conservatism in Cladding Hoop Stress Calculation Methodology**

[[

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## Attachment 5- Critical Pressure Relations with PRIME Creep Relations

[[

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## Attachment 6 - Detail Calculations

**Approach:**

[[

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