Proprietary Notice

This letter transmits proprietary information in accordance with 10CFR2.390. Upon removal of Enclosure 2, the balance of the letter may be considered non-proprietary.

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Project Number 691

BWROG-07026
May 22, 2007

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

SUBJECT: RESPONSES TO REQUESTS FOR ADDITIONAL INFORMATION (RAIS) DATED FEBRUARY 16, 2007, REGARDING THE BOILING WATER REACTOR (BWR) OWNERS' GROUP (BWROG) TOPICAL REPORT (TR) NEDO-33163, "HIGH BURN UP FUEL ROD GAP RELEASE FRACTIONS" (TAC NO. MD1764)

ENCLOSURES:
1) Responses to NRC RAIs (Non-Proprietary)
2) Attachment 1 (Proprietary)
3) GNF Affidavit

Enclosed please find the BWROG responses (Enclosure 1) to the NRC Requests for Additional Information (RAIs) on the subject Licensing Topical Report (LTR) NEDO-33148. One of the RAI responses involves computer input, which is included in Enclosure 2. This input is Proprietary in its entirety and as such no Non-Proprietary version is provided.

Please note that Enclosure 2 contains proprietary information of the type that GNF maintains in confidence and withholds from public disclosure. The information has been handled and classified as proprietary to GNF as indicated in its affidavit. The affidavit contained in Enclosure 3 identifies that the information contained in Enclosure 2 has been handled and classified as proprietary to GNF. GNF hereby requests that the information in Enclosure 2 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.390 and 9.17.

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Should you have additional questions please contact Rita Arndt (BWROG Project Manager) at (910) 675-6051 or Gregory Broadbent (BWROG AST Committee Chairman) at (601) 437-6224.

Sincerely,

Randy Bunt
BWR Owners' Group Chair

cc: Ms. Michelle Honcharik, NRC
Mr. Douglas Coleman, Energy Northwest
BWROG Primary Representatives
BWROG AST Committee

BWROG-07026

Enclosure 1

Responses to Requests for Additional Information (RAIs) dated February 16, 2007, Regarding the Boiling Water Reactor (BWR) Owners' Group (BWROG) Topical Report (TR) NEDO-33163, "High Burn Up Fuel Rod Gap Release Fractions" (TAC No. MD1764)

Non-Proprietary Information

Responses to Requests for Additional Information

RAI 1

The Pacific Northwest National Laboratory (PNNL) as a contractor for the U.S. Nuclear Regulatory Commission (NRC) has performed an audit calculation with FRAPCON-3.3 for the General Electric (GE)-10x10 full length rod design using the rod average powers provided in Figure 2.1 and the peak local powers provided in Figure 2.3. The axial power profiles were selected to approximate the local peak powers in Figure 2.3. The FRAPCON-3.3 calculated gap release fraction for Kr-85 was approximately 0.116 at end-of-life (EOL). This value is considerably larger than the 0.065 EOL calculated in Table A-6 for full length GE10x10 rods. The FRAPCON-3.3 calculated peak gap release was 0.122 between 50 to 55 GWd/MTU (rod average) while the peak value in Table A-6 was 0.087 at 42 GWd/MTU. The PNNL audit calculation used the Massih model in FRAPCON-3.3. This demonstrates that there is a considerable difference in Kr-85 release fraction between the audit calculation and the values presented in Appendix A for a given rod and power history. The source of the differences in release fraction need to be determined; for example, if the differences are in input values used, or if they are in the analysis models used, or in the application of the analysis models. This will allow the NRC and PNNL reviewers to determine if the differences are acceptable. A more exact audit calculation can be made if the input used for Appendix A calculations is provided.

a. *It is requested that BWROG provide the input values for those full length and part length designs that result in the peak gap fractions that will enable PNNL to perform a direct comparison to the gap release results given in Appendix A. It is requested that the input be provided for the GE12/14 design as well as for SVEA-96 Optima2 because the large difference in FGR can not be duplicated as shown in Figures 4.11 and 4.12. If the input used does not explain the differences then further examination will be needed on the analysis models and their application to the gap release fractions will need to be examined further.*

Response:
This evaluation applied the FRAPCON-3.1 code to determine the gap fractions. This version of the FRAPCON code was applied for two reasons. First, it was the version applied to generate the gap fractions in NUREG/CR-6703, which are currently approved for use in Table 3 of Reg. Guide 1.183. Secondly, at the time this evaluation was performed, FRAPCON 3.1 was the only version available for use.

The difference between the calculated Kr-85 gap fractions can be solely attributed to the code version. The FRAPCON 3.1 input files for the GE12/14 are listed in Attachment 1. When executed with FRAPCON 3.1, these inputs produce the Kr-85 results documented in NEDO-33163. The differences between the results for the GE12/14 and the SVEA-96 Optima 2 fuel rod designs are primarily due to the differences in the fuel surface roughness inputs used for each of these designs.

It should also be noted that software changes were made to more accurately represent the ANS 5.4 model as implemented in FRAPCON 3.1. Although these changes do not affect the Kr-85 results, there are impacts to the results for other radioactive isotopes. As described in Section 3 of NEDO-33163, these code revisions have been discussed with and evaluated by the PNNL personnel responsible for FRAPCON-3 code development and maintenance.

Any changes in results due to code versions are well bounded by the conservatisms in this evaluation. Not only are the rod power histories very conservative relative to actual operation but anticipated changes to the ANS 5.4 model by the standards committee would significantly reduce calculated gap fractions.

b. *Are there 8x8 fuel designs in reactor cores today? If so, when will these rods be discharged and are they considered to be in limiting positions that could result in large gap fractions? The issue is whether the 8x8 fuel designs should be considered for this review.*

Response:
The BWR industry is primarily using 10x10 fuel designs at this time. There are only 22 8x8 bundles in a BWR reactor at this time. These bundles are in low power locations, comply with Footnote 11, and are planned to be discharged within the next two cycles. On this basis, the 8x8 design need not be considered in this review.

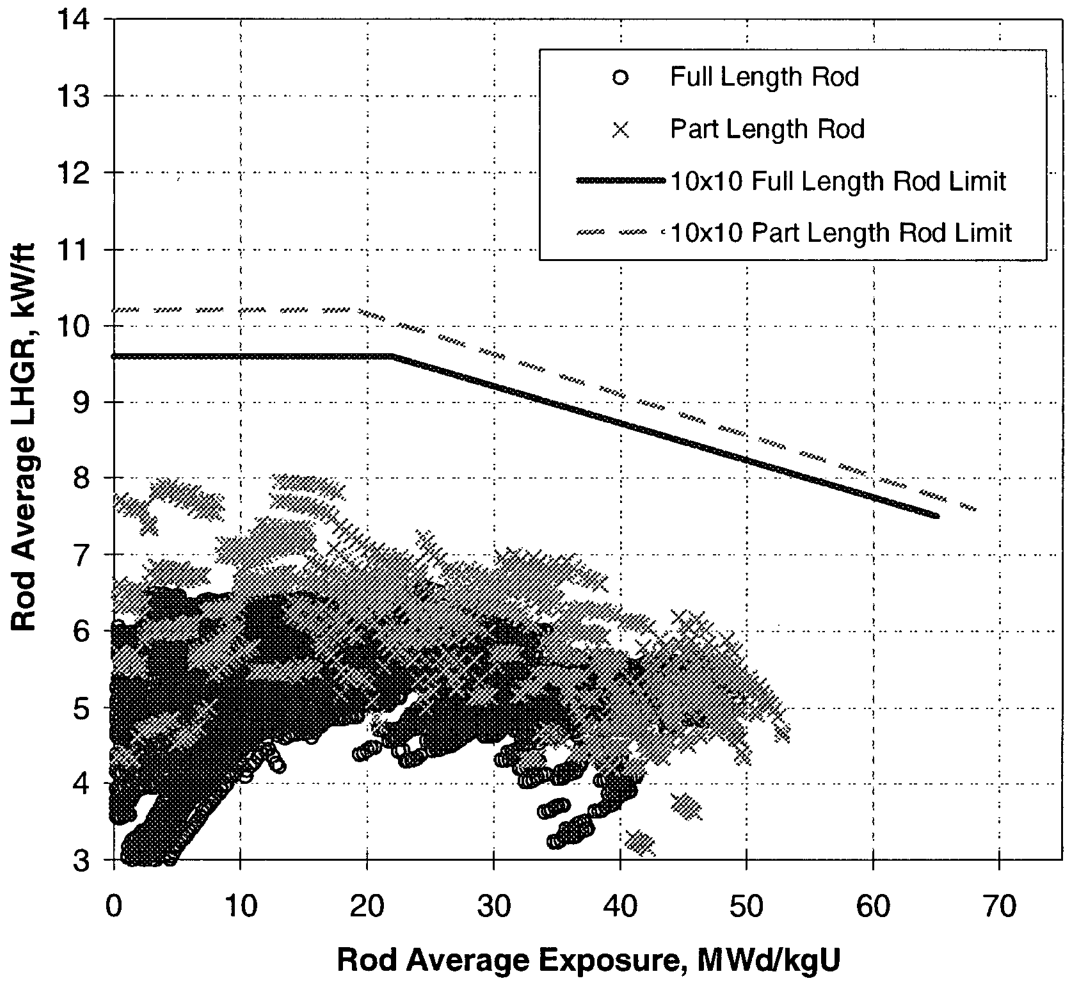
<u>RAI 2</u>

Please provide an example of how the rod average power versus burnup was determined for the curves in Figures 2.1 and 2.2 (e.g., provide a comparison of actual power histories used to determine the limit along with the limiting curve). An example for one fuel design is sufficient, preferably a design that operates the closest to the LHGR limit curves in Figures 2.1 and 2.2.

Response:

The bounding rod-average power versus burnup limits were developed to maximize rod gap fractions. Assuming the rods were operating on the LHGR curves reported in Section 2.3 of NEDO-33163, a conservatively low axial peaking factor was applied to maximize rod power over the entire exposure range. These results were then grouped by fuel type to arrive at the bounding curves in Figures 2.1 and 2.2. Experienced core designers at BWR licensees and fuel vendors then concurred with the expected bounding nature of these curves.

As an example, actual data from an aggressively burned GE14 bundle at an uprated BWR was plotted versus the bounding curves in Figures 2.1 and 2.2. As shown in the figure below, all the points are well bounded by the assumed limits. Thus, the curves reported in Figures 2.1 and 2.2 are considered con



RAI 3

The "proposed BWR non-LOCA gap fractions" provided in the table in BWROG-06009 letter, dated March 30, 2006 (ADAMS Accession No. ML060940464) are lower than the majority of gap fractions provided in Tables 4.1 and 4.2 of Enclosure 1 (NEDO-33163) that are stated to be the basis for the "Proposed BWR Non-LOCA Gap Fractions." Please explain why the gap fractions in BWROG-06009 do not agree (are lower) with those calculated in NEDO-33163.

Response:

Table 3 of Reg. Guide 1.183 reports the listed values as "non-LOCA" gap fractions since the "LOCA" gap fractions were previously listed in Table 1 for BWRs. These "non-LOCA" gap fractions are based on worst-case rod power histories and are consequently larger than the LOCA gap fractions based on core-average assumptions.

The only radiological event that these "non-LOCA" gap fractions are applied in the BWR radiological analyses is the fuel handling accident. From Table 6 of Reg. Guide 1.183, the BWR design basis radiological events are LOCA, main steam line break, control rod drop, and fuel handling accident. While the LOCA gap fractions are listed in Table 1 for BWRs, the main steam line break accident involves coolant activity rather than gap activity per Appendix D to Reg. Guide 1.183 and consequently does not apply gap fractions. The approved gap fractions for the control rod drop accident are assumed to be 10% for iodines and noble gases per Footnote 11 of Reg. Guide 1.183. Therefore, the only design basis BWR radiological analysis to which these "non-LOCA" gap fractions are applied is the fuel handling accident.

Many BWR licensees have incorporated the gap fractions in Table 3 of Reg. Guide 1.183 into their licensing bases. Consequently, this BWROG effort sought to maintain the same gap fractions, where possible, with bounding or relaxed power history assumptions relative to the restriction in Footnote 11. Although Tables 4.1 and 4.2 report higher gap fractions for some isotopes, the current gap fractions in Table 3 of RG 1.183 were found to remain applicable for all isotopes except alkali metals, when the conservatisms in the analysis were considered.

Tables 4.1 and 4.2 are based on every rod in the bundle being on the bounding power history curve simultaneously. However, this is not the case in actual operation, and there is always some local peaking distribution within the bundle. As described in Section 4.3 of NEDO-33163, even a small 10% reduction in the rod powers results in a 40-50% reduction in gap fractions. Based on the GE14 data applied in response to RAI #2, at least 50% of the fuel rods operate at least 10% below the peak rod, resulting in a bundle-average gap fraction of ~80% of the peak value. This conservatism alone resulted in bundle-average gap fractions that are within those in RG 1.183 with the exception of some 9x9 Kr-85 results and many alkali metal results. As Kr-85 is not significant in the radiological analysis and only slightly exceeded the 15% value in RG 1.183 for this small fraction of the operating fuel designs, the difference was ignored. Although the alkali metals are also not significant in the fuel handling accident, there were large differences between the bundle-average gap fractions and the RG 1.183 values, such that an increase in the RG 1.183 values was proposed.

RAI 4

Proprietary Enclosure 3 to BWROG-06009 (ADAMS Accession No. ML06940471) provided justification for not including fast transients due to reactivity insertions that are terminated by scram within a few seconds. The justification provided was that diffusion could not release any significant gas within the time frame of a few seconds.

a. *This justification does not agree with experimental evidence from reactivity insertion accident (RIA) experiments in Cabri (Reference 1 of this RAI set) and Nuclear Safety Research reactor (References 2 and 3 of this RAI set) where release fractions up to 20% are observed. There is evidence that release due to RIA is not diffusion controlled but due to release from fracture of grain boundaries. The issue of gap release fractions during RIA events may take considerable more time for review than non-RIA events. Therefore, it is recommended that this review be broken into two parts: 1) review of gap release fractions for events that do not involve large thermal or power transients and 2) review of gap fractions for RIA events. Assuming the BWROG agrees with this approach and to cover item 1 first, address RAI 4.b normal operation including anticipated operational occurrences (AOOs) and RAI 4.c for RIA release.*

b. *Are the gap release fractions proposed in the BWROG letter dated March 30, 2006, intended to replace those in Table 3 of Regulatory Guide (RG) 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors." The gap release fractions in Table 3 of RG 1.183 are for non-LOCA accidents, that do not involve large thermal or power transients (such as fuel handling accidents) but do include release due to normal operation and AOOs. Because AOOs are relatively mild in terms of thermal increase the release from these transients may be a combination of both diffusion and non-diffusion release. To justify why the TR does not include a release due to thermal transients from AOOs, please perform the following:*

   - *Provide a table of power increase and the time period at power for each AOO event. This information will be used to establish the range of rod powers and time at power during AOO events and address whether there are power ramp gap release fraction data from light-water reactor rods that span the range of AOO events for the burnup range of interest.*

Response:

As described in BWROG-06009, the impact on gap fractions from a fast transient was assessed based on a concern from the NRC Staff at the pre-submittal meeting in April 2004. As a steady-state code, FRAPCON could not be applied directly to generate gap fractions from a fast transient. Consequently, an approach using a diffusion time constant was applied.

BWR transients are grouped into fast transients, such as a turbine trip, that generally involve a large neutron flux spike that is terminated by a scram and slow transients, such as a loss of feedwater heating, where the core may settle into a new steady-state at a higher power for a short period.

The evaluation in Enclosure 3 to NEDO-33163 demonstrated that fast transients occur on a time scale too short to allow for any significant diffusion to occur into the gap before shutdown. This analysis was based on the power transient in Figure 2.1 of Enclosure 3. This feedwater controller failure transient has an extended duration due to the level runup and is terminated by a pressurization transient initiated from an overpower condition. As such, this event is considered to be representative of BWR fast transients. Any variation among plant types or AOOs is small and would be well bounded by the demonstrated margin in Figure 2.2 of Enclosure 3.

Slow transients involve measured core power increases, that are bounded on a core-wide level to ~20% by the APRM flux scram and <~35% on a local level by the fuel vendor's rod overpower criteria. This overpower criteria would exist only for the time necessary for operators to take corrective action, which is 10 minutes for transients as reported in ANSI/ANS-58.8-1994. From Figure 2.2 in Enclosure 3, it can be seen that the thermal time constant still remains greater than 600 seconds for power levels up to 135% of initial values, demonstrating that no significant diffusion would occur into the gap even during a slow AOO.

- *Provide additional power ramp gap release fraction data available to the BWROG that are not currently used in the FRAPCON-3 calibration and validation database (References 4 and 5 of this RAI set) particularly data at high burnup and short hold-time at power (i.e., minutes to a few hours). Please review the AOO events, the gap release fraction data, and the conservatisms in the calculation to demonstrate that the gap release fraction (stable or unstable isotopes) from these events can be ignored, bounded or accurately predicted by the proposed models.*

Response:
The only additional power ramp gap release fraction data available to the BWROG is that included in GEAP-22076, "Fuel Ramp Tests in Support of a Barrier Fuel Demonstration," UC-78, July 1984. This documentation has previously been supplied to NRC Staff in October 2006 during the ESBWR fuel audit.

All of the AOOs described above involve fuel temperature changes well below the melting point and do not result in any significant grain boundary fracturing as observed in the RIA tests. Only the rod withdrawal error has the potential for very limited centerline melt in a small portion of the fuel rod in very severe scenarios under some fuel vendor's approved methodologies. Consequently, any non-diffusion releases would be negligible relative to those currently evaluated by the diffusion model in the ANS 5.4 standard.

On these bases, there are no BWR AOOs that would impact the gap fraction. Therefore, there is no methodology or example analysis to present for those AOO events where the release is significant.

- *Based on the above, please provide a methodology and example analysis of gap release for those AOO events where release is not negligible.*

Response:
As described above, there are no BWR AOOs that would impact the gap fraction. Therefore, there is no methodology or example analysis to present for those AOO events where the release is significant.

b. *Please propose an approach to calculating the gap release fractions or a bounding estimate for RIA events. Identify if any non-LOCA events other than a control rod drop accident (e.g., rod withdrawal event) would exhibit both diffusion and non-diffusion releases.*

Response:
The regulatory guidance contains approved gap fractions for the RIA and these are not impacted by NEDO-33163. Therefore, an approach to calculating gap release fractions for RIA events is not provided.

RAI 5

The analysis in Section 4.1 of NEDO-33163 provides an upper bound for the EOL shutdown pressure. What was the assumed shutdown temperature?

Response:

Before the issuance of RG 1.183, the regulatory guidance in Safety Guide 25 indicated the pool decontamination factor assumed in the dose analysis of the fuel handling accident was dependent on the fuel rod pressurization being less than 1200 psig. Although NEDO-33163 addressed gap fractions, the opportunity was also taken to compute rod pressures as this parameter is an output from the FRAPCON code. In this evaluation, a water temperature of 200 °F was applied to conservatively bound the temperatures expected during fuel handling operations. The rod pressure was found to be less than 905 psig, which is significantly less than the 1200 psig limit in Safety Guide 25.

RAI 6

Section 4.2 of NEDO-33163 suggests that the gadolinia rods will be less limiting than non-gadolinia fuel rods based on current operation and FGR measurements from Reference 8. Please provide a copy of Reference 8. The assumption that gadolinia rods are less limiting is based on current operational practices but there is nothing to prevent future operational practices that would allow gadolinia rods to be more limiting than non-gadolinia rods. Please provide an approach/methodology that would allow confirmation that gadolinia rods will remain less limiting for future operation and if this is not confirmed the analysis methodology for gadolinia rods will be submitted to NRC for review.

Response:

Consistent with the analysis to support the current approved gap fractions developed in NUREG/CR-6703, NEDO-33163 neglected the effect of gadolinia (or "gad") rods as they are expected to be non-limiting with respect to gap fractions. To support this assumption, the field data is referenced in EPRI report TR-1003222. Also shown in Tables 2-6 and 2-7 of this report, the gap fractions of the gad rods are only 25-50% of the UO_2 (or "non-gad") rods. The BWR Owners' Group is unable to provide a copy of Reference 8. If required, the NRC is requested to contact EPRI directly to obtain said report.

This result is expected because gad rods do not operate at the power levels associated with non-gad rods due to the power suppression effect of the gadolinium and the reduced U-235 enrichments associated with gad rods. This reduced power level is also necessary from a rod mechanical perspective since the melting temperature of the gad rods is lower than non-gad rods. As a result of their lower power, gad rods also do not reach the extended burnups associated with non-gad rods. All these factors cause the gap fractions of gad rods to be less than the non-gad rods.

There are no conceivable changes to present or future operational practices that could cause the gad rods to be limiting with respect to gap fraction without review by licensees and appropriate revisions to this evaluation. Developments in fuel rod design or changes in operational practices that could appreciably impact the gap fractions of gad rods would receive significant technical and licensing reviews at both the fuel vendor and licensee levels as well as by the NRC Staff.

Considering the observed margin between the gad and non-gad rods and the lack of any potential changes to operational practices that could cause the gad rods to be limiting, approaches or confirmations that ensure that gad rods remain less limiting for future operation are not required.

BWROG-07026

Enclosure 3

Affidavit

Global Nuclear Fuel – Americas

AFFIDAVIT

I, Jens G. M. Andersen, state as follows:

(1) I am Consulting Engineer, Thermal Hydraulic Methods, Global Nuclear Fuel – Americas, L.L.C. ("GNF-A"), 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 Enclosure 2 of BWROG-07026, Randy Bunt (BWROG) to Document Control Desk (USNRC), *Responses to Requests for Additional Information (RAIs) dated February 16, 2007, Regarding the Boiling Water Reactor (BWR) Owners' Group (BWROG) Topical Report (TR) NEDO-33163, "High Burn Up Fuel Rod Gap Release Fractions" (TAC No. MD1764),* dated May 22, 2007. Enclosure 2 is proprietary in its entirety. The header of each page in this enclosure carries the notation "GNF Proprietary Information{3}." The superscript notation{3} refers to Paragraph (3) of this affidavit, which documents the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner or licensee, GNF-A 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 GNF-A's competitors without license from GNF-A 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 GNF-A customer-funded development plans and programs, resulting in potential products to GNF-A;

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 GNF-A, 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 GNF-A, 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 GNF-A. Access to such documents within GNF-A 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, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GNF-A 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) is classified as proprietary because it contains details of GNF-A's fuel design and licensing methodology.

The development of the methods used in these analyses, along with the testing, development and approval of the supporting methodology was achieved at a significant cost, on the order of several million dollars, to GNF-A or its licensor.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GNF-A's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GNF-A'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 GNF-A.

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.

GNF-A's competitive advantage will be lost if its competitors are able to use the results of the GNF-A 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 GNF-A 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 GNF-A 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 22nd day of May 2007.

Jens G. M. Andersen
Consulting Engineer, Thermal Hydraulic Methods
Global Nuclear Fuel – Americas, L.L.C.