Enclosure 3

MFN 08-562

Submittal of Licensing Topical Report (LTR) NEDE-33243P, Revision 2, "ESBWR Control Rod Nuclear Design"

Affidavit

GE-Hitachi Nuclear Energy, LLC

AFFIDAVIT

I, David H. Hinds, state as follows:

(1) I am General Manager, New Units Engineering, GE-Hitachi Nuclear Energy, 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 enclosure 1 of GEH's letter, MFN 08-562, Mr. Richard E. Kingston to U.S. Nuclear Energy Commission, entitled "*Submittal of Licensing Topical Report (LTR) NEDE-33243P, Revision 2, "ESBWR Control Rod Nuclear Design",*" dated July 3, 2008. The proprietary information in enclosure 1, which is entitled "*MFN 08-562 – Submittal of Licensing Topical Report (LTR) NEDE-33243P, Revision 2, "ESBWR Control Rod Nuclear Design"– GEH Proprietary Information,*" is delineated by a [[dotted underline inside double square brackets{3}]]. Figures and large equation objects 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 details of GEH's evaluation methodology.

The development of the evaluation process 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 3rd day of July 2008.

David H. Hinds
GE Hitachi Nuclear Energy

Enclosure 2

MFN 08-562

Submittal of Licensing Topical Report (LTR) NEDE-33243P, Revision 2, "ESBWR Control Rod Nuclear Design"

Non-Proprietary Version

GE Hitachi Nuclear Energy

3901 Castle Hayne Road
Wilmington, NC 28401

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LICENSING TOPICAL REPORT
ESBWR CONTROL ROD NUCLEAR DESIGN

NONPROPRIETARY NOTICE

This is a nonproprietary version of the document NEDC-33243P, Revision 2, where the proprietary information of NEDC-33243P, Revision 2 has been removed. The portions of NEDC-33243P, Revision 2 that have been removed are indicated by double square open and closed brackets as shown here [[ ]]. Figures and large equation objects of NEDC-33243P, Revision 2 that have been removed are also identified with double square brackets before and after where the object was to preserve the relative spacing of NEDC-33243P, Revision 2.

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please read carefully

The information contained in this document is furnished **for the purpose of supporting the NRC review of the certification of the ESBWR**, with the information here being used as ESBWR supporting reference. The only undertakings of GE Hitachi Nuclear Energy (GEH) with respect to information in this document are contained in contracts between GEH and any participating utilities, and nothing contained in this document shall be construed as changing those contracts. The use of this information by anyone other than that for which it is intended is not authorized; and with respect to **any unauthorized use**, GEH makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

Note of Changes:

NEDO-33243 Revision 1 issued in October 2007 has been revised. This Revision 2 of NEDO-33243 incorporated GEH responses to NRC RAI 4.2-18 and 4.2-19. The following pages are affected by this revision:

P.6 Table 2.2 is changed to include actual dimensions used in analyses.

P.16 Section 6 Conclusions is changed to include results of dimensional tolerances, in addition to the nominal results originally reported.

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1 Introduction

This report contains the ESBWR control rod nuclear analysis results, which have been revised from those in NEDE-33243P Revision 0 due to design changes. The control rod selected for the ESBWR design is a Marathon blade [1] with B_4C as the absorber (neutron poison) material and the capsule design adopted from Marathon-5S [2]. Because the equilibrium core design for ESBWR was performed with an S-lattice Duralife blade, the Marathon blade was designed such that its initial cold worth matched that of the Duralife blade. The B-10 poison in the blade was depleted as a function of time to determine the level of depletion that would reduce the cold worth of a quarter segment of the blade by 10%. This constitutes the end-of-life (EOL) of the blade. These depletion fractions are converted to EOL fluences to facilitate plant monitoring. The peak absorber tube heating rate is also provided. The final set of calculations involved developing axial profiles for blade depletion including the determination of peak rod depletion data.

The procedures outlined in NEDE-30931-8-P [3] are generally followed in these analyses. The three-dimensional Monte Carlo radiation transport code MCNP01A [4], a GEH Engineering Computer Program (ECP), was the principal tool used in this work. The following sections detail these calculations and present results.

2 Methodology

2.1 Depletion Methodology

The blade worth is defined as $1\text{-}k_{con}/k_{unc}$, where k_{con} and k_{unc} are the controlled and uncontrolled multiplication factors, respectively.

The blade lifetime is defined as the point in time when the cold worth of a quarter segment of the blade is 10% less than the cold worth at the beginning of life (BOL) of the blade. The standard way of presenting the blade lifetime is as the EOL thermal fluence in units of snvt (sextillion or 10^{21} neutrons/cm^2), which is derived from the EOL depletion fraction. In order to obtain the depletion fraction, a set of runs is made with MCNP01A, where the removal rate of the poison in the absorber tubes is held constant for a period of time. Using this reaction rate, a new set of atomic densities is calculated and used to update the MCNP input and the code runs again. The depletion calculations are performed at hot 40% void conditions. At each time step a calculation is also performed at cold conditions. The cold k_{con} at each time step is used to determine the worth and reduction in worth from BOL. This process is continued for several time steps and a depletion profile vs. worth is established. It is assumed that the fuel is in a fresh condition throughout this depletion process. In the present analyses, [[ ]] time steps of [[ ]] days each were taken. The standard depletion equation for B-10 is given as

$$\frac{dN_{B-10}}{dt} = -(N * \sigma)_{B-10} \qquad (1)$$

Here, σ is the reaction rate per unit nucleus obtained from the MCNP run at each time step (Δt in width) and the new atomic density N_{B-10}, is given as

$$N_{B-10} = N_{B-10,prev} * \exp(-\sigma \Delta t) \qquad (2)$$

Once the depletion fraction equivalent to a 10% worth reduction is determined, the following procedure is used [3] to convert this into the EOL thermal fluence in snvt.

A quantity called [[ ]] is defined as

[[ ]] (3)

Here, [[

]] and

[[

]]

Thus, [[ ]] is given as

[[ ]] (4)

2.2 Heating Rate

The limiting heating rate (in units of Watt per g of B_4C) in the blade occurs at BOL conditions. The heating rate calculations at BOL are conservative since the heat generation rate decreases with the blade depletion. The heating rate is calculated using the value of μ, the ratio of the average absorptions in the poison in the blade to the total fissions in the node (see Section 2.1), the average energy deposited in the poison per absorption via the (n,α) reaction (2.79 MeV), and the total number of fissions in the node determined using the power density. In addition to the average value, the heating rate in the peak absorber tube is also determined using the radial peaking factors across the blades. For the heating rate calculation the limiting value is at BOL and this radial profile is used to determine the peak rod heating.

2.3 Axial Depletion

Control rod nuclear lifetime, as described in Section 2.1, is defined as the depletion limit corresponding to a 10% reduction in the cold worth from BOL conditions. The mechanical lifetime is defined as the total average depletion that corresponds to the allowable helium pressure limit in the limiting absorber tube. The rod with the highest burnup is determined by using the depletion profile radially across the blade. An average profile over the blade lifetime (equivalent to 10% reduction in worth) is used to determine the average peak rod depletion since this is more representative over the blade lifetime. This combined with a limiting axial profile will provide the average peak rod depletion.

The main assumption used in these analyses involves the use of existing nominal (typical) and limiting (worst-case) EOL axial burnup profiles that were developed for BWRs and ABWRs. The control rod is shorter [[ ]] in the ESBWR and the profiles for the shorter blade are not developed. Therefore the [[ ]] profiles are assumed to be valid for the short blade. It must be noted that these profiles were developed as a standard set applicable to all BWRs and have been used over the years for various blade designs in their current form.

The standard normalized axial profiles for the nominal and limiting are presented in Table 2.1. The nominal profile is top-peaked and typically represents a core where standard blade patterns are used over the operating cycle. The limiting profile is flatter and is seen in cores operating with the control cell core concept, where a few blades see deep-shallow exchanges over the cycle. The mechanical limit can be adjusted by removing some of the absorber material at the bottom of the blade and creating a plenum region. The standard profiles are plotted in Figure 2.1

2.4 Computer Codes and Calculational Model

MCNP01A, is a fully qualified code that is based on MCNP4A [5] and is a continuous energy Monte Carlo radiation transport code. The cross section set used is from the ENDF/B-V library [6]. The combination of MCNP and ENDF/B-V has been qualified for use in Light Water Reactor calculations [7,8]. The code was run in iterated source (criticality) mode with 2 million histories typically leading to standard deviations in the critical eigenvalue of approximately 0.0005.

The model was run with a single bundle with the surrounding water gap with the ESBWR nodal pitch of [[ ]]. Fully reflective boundary conditions were used. Continuous energy cross section sets at the appropriate fuel and moderator temperatures were used including the correct bound-scattering data for hydrogen in water. Each fuel rod is individually modeled with two concentric rings of fuel pellet and cladding. The control rod model includes the individual absorber tubes (square tubes) and the tie-rod. To account for the self-shielding effect of neutron absorbers, each absorber capsule is modeled as composed of multi-region concentric rings. A GE14 10x10 lattice with an average enrichment of [[ ]] in U235 and [[ ]]

Gd rods of [[ ]] w% was used for the analyses. This was the main lattice type in the predominant bundle in the ESBWR equilibrium core.

Figure 2.2 shows the lattice used for the analyses. The enrichment values shown in this figure translate as [[ ]] w% U235 [[ ]] etc. The rods shown with entries 45 through 51 are Gd rods with [[ ]] w% U235 and [[ ]] w% Gd. The water rods are shown with entries of -77. The control rod will be located in the left and top water gaps.

Figure 2.3 shows the MCNP model with the blade. It must be noted in Figure 2.3, that the lattice in Figure 2.2 has been rotated counter clockwise by 90°. As shown in Figure 2.3, the absorber capsule region is modeled as [[ ]] concentric rings with radii [[ ]], [[ ]], [[ ]], and [[ ]], respectively, from center going outward.

The blade dimensions used in the analyses are presented in Table 2.2. The radius of curvature of the tie-rod is [[ ]] where as the analyses used a radius of [[ ]]. This difference was shown to have a negligible effect on the final results. Various analyses with [[ ]] absorber capsule ID tolerances were also performed, the results indicate the control rod nuclear life is not affected significantly by the varying capsule ID within tolerance limits.

Table 2.1 Nominal and Limiting B-10 Burnup Profiles

Axial Node	Nominal	Limiting
[[		
		]]

Table 2.2 Blade Dimensions Used in Analyses

Description	Dimension	
	(inches)	(cm)
[[		
		]]

[[

]]

Figure 2.1 Nominal and Limiting Axial Profiles

[[

]]

Figure 2.2 Lattice Used in ESBWR Control Rod Analyses

[[

]]

Figure 2.3 MCNP Model of Lattice with Marathon Blade

3 Depletion Calculations and EOL Fluence

The depletion calculations were performed using [[ ]] steps each of [[ ]] days in duration. Since the blade is fairly uniform in the axial direction, a set of calculations was performed with all absorber tubes filled with B_4C. In addition to the cold eigenvalues, hot 40% void eigenvalues are also presented, as shown in Table 3.1. The change in cold worth is plotted against the B-10 depletion percentage and the data fitted. Using the fit, the depletion limit that yields a 10% worth reduction is determined to be approximately [[ ]] B-10 depletion, as demonstrated in Figure 3.1.

Using these depletion fractions, the EOL fluence is calculated using equations 3 and 4. The EOL fluence for ESBWR Marathon blade is determined to be [[ ]] snvt.

Table 3.1 Depletion of ESBWR Marathon Blade

[[

]]

[[

]]

Figure 3.1 Marathon Blade Depletion Curve

4 Control Rod Heating Rate

The relative heating profile across the span of the control rod with the nominal diameter is presented in Table 4.1. The heating rate profiles at different burnup steps have been examined and it is concluded that these profiles are insensitive to the burnup of the blade. They are also insensitive to the size of the absorber tubes.

The calculated nominal heating rate, as described in Section 2.2, is [[ ]] watt/g-B_4C. The peak tube heating rate is [[ ]] watt/g-B_4C.

Table 4.1 Marathon Normalized Radial Heating Rate

[[

]]

5 Axial Depletion of Blade

The typical axial depletion profiles discussed in Section 2.3 were used in combination with the radial depletion profile to establish the average depletion fraction in the limiting rod. The limiting rod is the rod at the outer end of the blade. These analyses were performed assuming that all the tubes are filled with absorber material over the entire length of the control rod. In the final design this rod will be empty for about [[ ]] from the bottom of the blade. Thus these results present the bounding depletion rates. Table 5.1 presents the results of axial profiles of B-10 depletion under nominal and limiting patterns.

The peak average EOL B-10 depletion is approximately [[ ]] in the limiting tube. Since the mechanical limit is approximately equal to [[ ]] depletion and this value exceeds this limit, the plenum region at the bottom is introduced to accommodate the released helium gas and provide pressure relief within the tube.

Table 5.1 Marathon Axial Depletion Profiles for 10% Worth Reduction

[[

]]

6 Conclusions

The nuclear analyses for the Marathon blade, which is the current design of control equipment for the ESBWR initial core, estimate the EOL lifetime fluence as [[ ]] snvt. The average heat generation is [[ ]] W/g of B_4C. The depletion fraction for the most limiting tube for a nominal axial burnup profile is [[ ]] local depletion. For the limiting axial burnup profile, the highest depleted absorber tube can reach up to [[ ]] quarter segment depletion.

7 References

1. NEDE-31758P-A "GE Marathon Control Rod Assembly," October 1991.
2. NEDE-33284P Revision 0, "Marathon-5S Control Rod Assembly," September 2006.
3. NEDE-30931-8-P Revision 8, "GE BWR Control Rod Lifetime," June 2007.
4. MCNP01A: General Electric version of Los Alamos National Laboratory code, MCNP – General Monte Carlo N-Particle Transport Code, DRF J11-02538, March 1995.
5. MCNP4A - A General Monte Carlo N-particle Radiation Transport Code, Version 4A, LA-12625, March 1994.
6. R. Kinsey, Ed., "ENDF/B Summary Documentation," BNL-NCS-17541 (ENDF-201), 3rd ed. (ENDF/B-V), Brookhaven National Laboratory (1979, several revisions)
7. S. Sitaraman, "MCNP: Light Water Reactor Critical Benchmarks," NEDO-32028, General Electric Nuclear Energy (1992).
8. S. Sitaraman and F. Rahnema, "Criticality Analysis of Heterogeneous Light Water Reactor Configurations", Nuclear Science and Engineering, 113, March 1993.