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LTR-NRC-12-67

September 19, 2012

Subject: Resolution of Open Items from NRC Audit on WCAP-16182-P-A, Revision 1, "Westinghouse BWR Control Rod CR 99 Licensing Report – Update to Mechanical Design Limits" (Proprietary/Non-Proprietary)

Enclosed are the proprietary and non-proprietary versions of, "Resolution of Open Audit Items from NRC Audit on WCAP-16182-P-A, Revision 1, 'Westinghouse BWR Control Rod CR 99 Licensing Report – Update to Mechanical Design Limits.'" This audit was held at the Rockville, MD office on August 22, 2012.

Also enclosed is:

1. One (1) copy of the Application for Withholding Proprietary Information from Public Disclosure, AW-12-3543 (Non-Proprietary), with Proprietary Information Notice and Copyright Notice.
2. One (1) copy of Affidavit (Non-Proprietary).

This submittal contains proprietary information of Westinghouse Electric Company LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding Proprietary Information from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference AW-12-3543, and should be addressed to J. A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, Suite 428, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066.

Very truly yours,

J. A. Gresham

J. A. Gresham, Manager
Regulatory Compliance

Enclosures

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AW-12-3543

September 19, 2012

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-12-67 P-Attachment, "Resolution of Open Items from NRC Audit on WCAP-16182-P-A, Revision 1, 'Westinghouse BWR Control Rod CR 99 Licensing Report – Update to Mechanical Design Limits '" (Proprietary)

Reference: Letter from J. A. Gresham to Document Control Desk, LTR-NRC-12-67, dated September 19, 2012

The Application for Withholding Proprietary Information from Public Disclosure is submitted by Westinghouse Electric Company LLC (Westinghouse), pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary information for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-12-3543 accompanies this Application for Withholding Proprietary Information from Public Disclosure, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to the proprietary aspects of the application for withholding or the accompanying affidavit should reference AW-12-3543, and should be addressed to J. A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, Suite 428, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance

Enclosures

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared J. A. Gresham, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

J. A. Gresham

J. A. Gresham, Manager
Regulatory Compliance

Sworn to and subscribed before me
this 19th day of September 2012

Anne M. Stegman

Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Anne M. Stegman, Notary Public
Unity Twp., Westmoreland County
My Commission Expires Aug. 7, 2016
MEMBER, PENNSYLVANIA ASSOCIATION OF NOTARIES

(1) I am Manager, Regulatory Compliance, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse Application for Withholding Proprietary Information from Public Disclosure accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of

Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use 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 a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in LTR-NRC-12-67 P-Attachment, "Resolution of Open Items from NRC Audit on WCAP-16182-P-A, Revision 1, 'Westinghouse BWR Control Rod CR 99 Licensing Report – Update to Mechanical Design Limits'" (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter, LTR-NRC-12-67, and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with Westinghouse's request for NRC approval of WCAP-16182-P-A, Revision 1, and may be used only for that purpose.

This information is part of that which will enable Westinghouse to:

(a) Obtain NRC approval of WCAP-16182-P-A, Revision 1, "Westinghouse BWR Control Rod CR 99 Licensing Report – Update to Mechanical Design Limits."

(b) Extend the mechanical lifetime of Westinghouse BWR control blades.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of this information to its customers for the purpose of assisting customers in obtaining license changes.

(b) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar fuel designs and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

Proprietary Information Notice

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

Copyright Notice

LTR-NRC-12-67 NP-Attachment
TAC No. ME2630

Resolution of Open Items from NRC Audit on WCAP-16182-P-A, Revision 1, "Westinghouse BWR Control Rod CR 99 Licensing Report – Update to Mechanical Design Limits" (Non-Proprietary)

September 2012

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

Open Item #1

Provide a full table of results based on [ ]^{a,c} with the respective Design Ratios. Include the [ ]^{a,c} intensity and the Design Ratios for all load cases in the topical report using the models of record. [ ]^{a,c} and representative plots of the [ ]^{a,c} for the limiting load case. Provide this data for all three lattices.

Answer 1

The models of record used in WCAP-16182-P-A, Rev. 1 are documented in the following two internal Westinghouse calculation reports:

1. BTM 09-0624, rev 0, "BWR Control Rod CR 99 for BWR/2-4 and BWR/6 Reactors with D- and S-lattice. Mechanical end of Life prediction and Stress analysis," 2009
2. BTA 07-0400, rev 0, "Stress Analysis of Control Rod CR 99 for BWR Reactors with C-lattice,"2007.

Description of finite element models (FEM)

Data contained in Table 1 was used as input to the FE-models. Figure 1 shows a representation of the boundary conditions used in the models. Figure 2 shows where pressure loads were applied during the analysis. The scram force application is shown in Figure 3.

Table 1 Material data and allowable stress according to WCAP-16182-P-A, Rev 1 and ASME-NB.

Temp, °C	20	85	300	310	350

[ ]^{a,c}

a,c

Figure 1 [

]a,c [1]

a,c

Figure 2 [

]a,c

[1] An ANSYS Work Bench model has been used to simplify the visualization of boundary conditions and applied loads.

a,c

[

]

Figure 3 [

]a,c

Two load cases were analyzed using finite element analysis for the stress evaluation consistent with what is presented in WCAP-16182-P-A, Rev. 1. The first case analyzes a pressure load applied at operating conditions and end of life (EOL), and the second case analyzes a cold scram load at EOL. Both analyses were carried out for S, D and C lattice plants. The results of each analysis are presented as follows:

Pressure load at Operating conditions and EOL (S & D Lattice)

For this analysis, an internal helium pressure of [ ]^{a,c} and a reactor pressure of [ ]^{a,c} were used. Figure 4 shows the results of this analysis. Table 2 contains a summary of the calculated stresses and design ratios.

a,c

Figure 4 Pressure load results at [ ]^{a,c}

Table 2 Summary of calculated stresses and design ratios in the analysis of a pressure load at end of life (S- & D-lattice).

a,c

[ ]

[2] WCAP-16182-P-A, Rev. 0 use stress limits according to [ ]a,c

Cold scram load at EOL (S & D Lattice)

For this analysis, an internal helium pressure of [ ]^{a,c} and a reactor pressure of [ ]^{a,c} were used, consistent with a temperature of [ ]^{a,c} Figure 5 shows the results. Table 3 contains a summary of the calculated stresses and design ratios for the analysis.

a,c

Figure 5 Cold tensile scram results for MEOL [ ]^{a,c}

Table 3 Summary of calculated stresses and design ratios in analysis of a pressure load [ ]^{a,c} and scram with inoperative buffer at end of life (S- & D-lattice).

a,c

Pressure load at Operating conditions and EOL (C Lattice)

For this analysis, an internal helium pressure of [ ]a,c and a reactor pressure of [ ]a,c were used. Figure 6 shows the results. Table 4 contains a summary of the calculated stresses and design ratios for the analysis.

a,c

Figure 6 Pressure load at MEOL [ ]a,c

Table 4 Summary of calculated stresses and design ratios in the analysis of a pressure load at end of life (C-lattice).

a,c

Cold scram load at EOL (C Lattice)

For this analysis, an internal helium pressure of [ ]a,c and a reactor pressure of [ ]a,c were used, consistent with a temperature of [ ]a,c Figure 7 shows the results. Table 5 contains a summary of the calculated stresses and design ratios for the analysis.

a,c

[ ]

Figure 7 Cold scram load at MEOL [ ]a,c

Table 5 Summary of calculated stresses and design ratios in analysis of a pressure load [ ]^{a,c} and scram with inoperative buffer at end of life (C-lattice).

a,c

Open Item #2

Provide supporting documentation of the convection surface coefficient and thermal link elements. Provide a summary of the thermal model and thermal link elements as documented in BR 92-345 and BTA 03-139.

Answer #2

Summary of BR 92-345

The report presents a study performed to determine the heat transfer coefficients at control rod surfaces in the Swedish BWRs [ ][a,c] with the following range of assumptions:

- [ ][a,c]
- [ ][a,c]
- [ ][a,c]
- [ ][a,c]
- [ ][a,c]

It was determined that the heat transfer coefficient was between [ ][a,c]

Summary BTA 03-139

Convection Surface Coefficient

Based on the heat transfer data calculated in BR 92-345, a conservative equation for calculating the convection surface coefficient at the control rod blade wing surface can be expressed as:

[ ][a,c] Eq. 1

where q is the surface heat flow in W/(m^2 °K).
The first term reflects the forced convection (macro convection) and the other term reflects the possible occurrence [ ][a,c] The heat transfer coefficient is below or in the lower range of what was determined in the study in BR 92-345 and is therefore conservative.

Thermal link element

Thermal convection between pin and blade is modeled in the thermal finite element model by link elements. [ ][a,c] Therefore, the thermal conductance, h_{int} (W/m^2 °K), across the B_4C/stainless-steel interface can be described as:

[ ]a,c Eq. 2

where [

]a,c The helium gas conductivity, k_g (W/m °K), may be written as:

$$k_g = aT^b$$ Eq. 3

The properties of the surfaces and the gap width play a role in the interfacial heat transfer as well. Since the gap width is assumed to be [ ]a,c the gas conductivity function must be completed to reveal the [

]a,c. It can be written according to:

a,c

[ ] Eq. 4

where

λ_0	=	Property of helium (Pa, m)
P	=	gas pressure (Pa)
R_m	=	the mean contact surfaces roughness (m)
$G_0(\varphi)$	=	peak to peak gap size where φ = the circumferential angle around the gap.

[ ]a,c Eq. 5

R_1 and R_2 are the estimated [ ]a,c for the HIP B_4C pin and stainless steel, respectively, in meters. [ ]a,c

At the contact points ($G_0 \equiv 0$), where the pin rests in the hole, [

]a,c

a,c

[ ] Eq. 6

where k_{B_4C} and k_{ss} are the thermal conductivity for B_4C and stainless steel, respectively. [

]a,c and H is the Mayer hardness of the softer material (stainless steel). It should be noted that the interfacial heat transfer in [

]a,c

The equation describing the convection link element in ANSYS is:

$$q = h_{\text{int}} \cdot A_i \cdot \left(T_j - T_k\right)$$ Eq. 7

where

q	=	heat flow rate (W).
h_f	=	film coefficient (W/m^2 °K).
A_i	=	area* for convection link element (m^2).
T_j, T_k	=	link temperatures (°K) at end nodes j and k

The areas of the convection link elements used have been calculated with respect to the local area to be simulated by the link in the calculation model. This means that the areas are dependent on nodal distribution and the number of elements used in the model.

Open Item #3

Provide an explanation why cracks in the control rod blade are not a failure of the design.

Answer to #3

The task of the BWR control rod is to be able to shutdown the reactor under all circumstances. One requirement for the control rod to be able to fulfill this task is that it contains the calculated amount of absorber material at all times to ensure the calculated reactivity worth is maintained. Another requirement is that the geometrical integrity is maintained in order to be inserted into the core.

If an IASCC crack (or other crack) appears in the absorber hole wall in a CR 99 control rod, it still meets the requirements above. It has been shown through testing and operational experience that the absorber material, i.e. hot isostatic pressed boron carbide, is retained within the absorber holes. It has also been shown that the withdrawal or insertion of the control rod, including during a scram, is not affected by such a crack.

[ ]^{a,c} (see response to Open Item #5).

Since the CR 99 control rod meets the requirements of retained reactivity worth as well as retained mechanical integrity, free from distortion, an IASCC crack in the blade wing is not regarded as a failure of design.

Open Items #4 and #6

[

]^{a,c}

Answers to #4 and #6

[

]^{a,c}

The [ ]^{a,c}, is a code developed to be used in stress evaluations of control rods and other reactor shut down systems. Because this code is directly applicable to control rods and shut down systems in LWRs, this is a more appropriate code to use in control rod stress evaluations. This code [ ]^{a,c} as opposed to [ ]^{a,c}, and results in a [ ]^{a,c} when compared to [ ]^{a,c}. The proposed allowable [ ]^{a,c} formulation in WCAP-16182-P-A, Rev. 1 is conservative compared to [ ]^{a,c}

a,c

Figure 8 Allowable stress as a function of temperature based on definitions in WCAP 16182-P-A, Rev. 1, [ ][a,c]

The formulation of allowable stress used in WCAP 16182-P-A, Rev 1,

$$S_m = \min\{0.9 \cdot R_{p0.2}(T); R_m(T)/3\}$$

was developed based on results from plastic analysis following ASME section III Division 1 NB-3228.3. The proposed formulation results in comparable allowable loads as plastic analysis following ASME NB-3228.3.

Previous Westinghouse experience has shown that the limiting load case for control rod CR 99 is the cold scram with inoperative buffer at end of life. This load case has been evaluated following the methodology presented in WCAP 16182-P-A, Rev 1 and documented in internal Westinghouse report BTM 09-0624 rev 0 (provided for review during the Audit) for S- and D-lattice control rods. In the following example the same control rod has been evaluated using the plastic analysis described in ASME NB-3228.3 with the following assumptions applied:

1. The material behavior of stainless steel 316L can be described by [ ][a,c] flow theory.
2. A [ ][a,c] are calculated based on material specifications, that is [[3]][a,c].

[3] Westinghouse performs tensile tests on each batch of materials arriving to the factory and can therefore state that every stainless steel sheet used in the manufacturing of control rods fulfills the material specification. That is, the used material definition in the calculation is conservative.

[ ]a,c

3. Yield strength is defined as 0.2% permanent deformation.

[ ]a,c

Figure 9 Plastic material data [ ]a,c methodology

The result from the plastic analysis in the case of cold scram with inoperative buffer at end of life gives the following results, Figure 10:

[ ]a,c

A stress evaluation following WCAP-16182-P-A, Rev. 1 of the same load case (BTM 09-0624 rev 0) results in [ ]a,c, as presented in Table 3.

Comparison of these two calculations shows that the stress evaluation calculated according to WCAP-16182-P-A, Rev. 1 and ASME NB-3228.3 results in comparable maximum allowed load on the control rod.

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[4] [ ]a,c

a,c

Figure 10 Results from plastic analysis of S- and D-lattice CR 99 (BTM 09-0624 rev 0). The displacement has been calculated at the surface where the scram force is applied.

Open Item #5

Provide an explanation why through wall plastic strain does not have an adverse effect on the control rod blade function.

Answer #5

The strain in the control rod is governed by core oscillations and the geometry of the control rod blade wing. Assuming fresh material, maximum equivalent total strain was calculated to [ ][a,c]

For fresh stainless steel the maximum total strain is much lower than fracture strain, as shown in Figure 11. This is also true for irradiated stainless steel. [ ][a,c]

a,c

Figure 11 Tensile tests of fresh and irradiated stainless steel 316L.

For highly irradiated stainless steel the conservative assumption is that [ ][a,c] in the control rod blade wing. If [ ][a,c] in the control rod blade wing during a seismic event it will not [ ][a,c] of load cycles and the stress [ ][a,c] being well below the [ ][a,c] of stainless steel 316L. In Figure 12 the [ ][a,c] is plotted as a function of [ ][a,c]. The calculations assume [ ][a,c] in the middle of the control rod (axially). This assumption is [ ][a,c] because maximum bending stress is located axially in the middle of the control rod [ ][a,c]

[

]a,c

The conclusion is that the straining of the wall will not influence the control rod worth. It is highly unlikely that damage in the stainless steel evolves due to bending stresses [

]a,c

Therefore, there is no risk of boron loss due to bending stresses and as a result, bending stresses will not have any impact on control rod worth.

a,c

Figure 12 [*]a,c.*

5 [ ]a,c

Open Items #7 and 8

Explain that bending stresses due to seismic events are covered by the experimental testing and not included in the analysis. Provide the bending stress results comparing CR99 to CR85 to show that the experimental data from the CR85 testing is valid for the CR99.

Answers #7 & #8

Bending stress in the control rod develops due to vibrations in the core during a seismic event. During insertion of the control rod the deformation of the channels is transferred into the control rod. Thus, bending stress in the control rod is caused by an imposed deformation and should therefore be treated as a secondary stress.

The bending stress should be evaluated against the 3*S_m criterion if linear elastic analysis is used. In ASME the 3*Sm criterion is used to prove that the load cycling is elastic after initial shake down and that no cyclic deformation is built up. [

]a,c

Testing has shown that a Westinghouse control rod CR 85 can be inserted (scramed) several times into an oscillating core [ ]a,c. The testing was performed with a cell of 4 channels and the control rod in the center. The channels were forced to oscillate with amplitude by applying a time varying deformation at the axial center of the channels. When the channels were oscillating with designed amplitude and frequency the control rod was scramed into the 'core'. [

]a,c After the testing it was concluded that:

1. [ ]a,c
2. [ ]a,c
3. [ ]a,c

The similar geometry of CR 85 and CR 99 make the results for CR 85 valid for CR 99:

a,c

[ ]

The number of cycles during a seismic event would be very few. This means that if the control rod is damaged, [

]^{a,c}

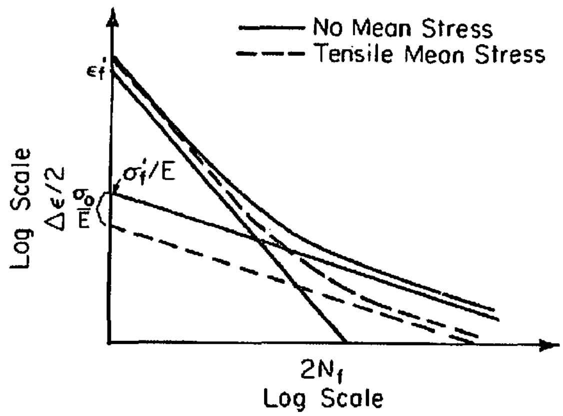

Figure 2.23 Morrow's mean stress correction to the strain–life curve for a tensile mean.

Modifications to the strain–life equation have been made to account for mean stress effects. Morrow [18] suggested that the mean stress effect could be taken into account by modifying the elastic term in the strain–life equation [Eq. (2.41)] by the mean stress, σ_0.

$$\frac{\Delta\epsilon_e}{2} = \frac{\Delta\sigma}{2E} = \frac{\sigma_f' - \sigma_0}{E}(2N_f)^b \qquad (2.48)$$

The strain–life equation, accounting for mean stresses is, then,

$$\frac{\Delta\epsilon}{2} = \frac{\sigma_f' - \sigma_0}{E}(2N_f)^b + \epsilon_f'(2N_f)^c \qquad (2.49)$$

Figure 13 [ ]^{a,c}[6].

The helium pressure inside the control rod will not change during a seismic event and will therefore only have an influence on the mean stress in the control rod. Thus, the helium pressure will not add to any damage that an oscillating core will cause in the control rod.

Westinghouse compared the bending stresses in CR 85 and CR 99 by finite element simulations. [ ]^{a,c} was applied to the control rods as a prescribed deformation varying linearly with distance from the center of the control rod, as shown in Figure 14. The geometries in the models were defined by average dimensions (average of maximum and minimum tolerance).

[6] J. A. Bannantine et. al. (1989), "Fundamentals of Metal Fatigue Analysis," Prentice Hall.

Table 6 Applied maximum deformation in finite element models.

[ ]a,c

The result from the finite element simulations show that the bending stress that evolves in the control rod due to seismic deformation in CR 85 and CR 99 are comparable, as illustrated in Figure 15 and Figure 16, thus proving, that the scram testing of the CR 85 into an oscillating core is valid for CR 99.

[ ]a,c

Figure 14 Prescribed deformation varying linearly with distance to center of control rod.

7 [ ]a,c

a,c

Figure 15 [ ]^{a,c} equivalent stress as a function of Y-coordinate in viewed coordinate system for both CR 99 and CR 85.

a,c

[ ]

Figure 16 Contour plots of [ ]^{a,c} equivalent stress in CR 99 and CR 85.

Open Item #9

Please describe the surveillance and inspection program Westinghouse has in place for its control rod blades.

Answer to #9

As shown in References 1, 2 and 3, Westinghouse has been conducting and continues to conduct an extensive surveillance program for all BWR control rod blade (CRB) designs (CR70, CR82, CR99, etc.). The surveillance program includes, at a minimum, visual inspections to confirm the integrity of the CRBs. The surveillance program includes additional inspections as needed, such as detailed blade measurements (profilometry), neutron radiography and hot cell examinations to determine material behavior and changes in properties as a function of neutron irradiation. Westinghouse pays special attention to leading CRBs (rods that reach the highest B-10 depletion). As shown over the last forty years, Westinghouse is committed to its rigorous surveillance program and will continue to inform the NRC of these inspections on an ongoing basis as additional information is gathered from this surveillance program.

References:

1. Ledergerber, G. et al., "Mechanical Performance of the Westinghouse BWR CR 99 Control Rod at High Depeltion Levels," 2011 Water Reactor Fuel Performance Meeting; Chengdu, China, Sept. 11-14, 201.
2. Seltborg, P. and Jinnestrand, M., "Assessment of the Mechanical Performance of the Westinghouse BWR Control Rod CR 99 at High Depletion Levels," PHYSOR 2012; Knoxville, TN, April 15-20, 2012.
3. Seltborg, P. et al., "Westinghouse BWR Control Rod CR 99 – Towards Flawless Operability," TopFuel 2012 – Reactor Performance Meeting; Manchester, United Kingdom, September 2-6, 2012.