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LTR-NRC-13-26

April 30, 2013

Subject: Supplemental Information on End-of-Life Seismic/LOCA calculations for the AP1000 Pressurized Water Reactor (Proprietary/Non-Proprietary).

Enclosed are copies of the proprietary and non-proprietary versions of supplemental information related to the end-of-life Seismic/LOCA calculations for the **AP1000®** Pressurized Water Reactor (PWR). This supplemental information addresses the concern discussed in NRC information notice IN-2012-09 and the questions contained in the requests for additional information (RAIs).

Also enclosed is:

1. One (1) copy of the Application for Withholding Proprietary Information from Public Disclosure, AW-13-3704 (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-13-3704 and should be addressed to James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, Suite 428, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066.

Very truly yours,

James A. Gresham, Manager
Regulatory Compliance

Enclosures

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AW-13-3704

April 30, 2013

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-13-26 P-Attachment, "Supplemental Information on End-of-Life Seismic/LOCA calculations for the AP1000 Pressurized Water Reactor" (Proprietary)

Reference: Letter from James A. Gresham to Document Control Desk, LTR-NRC-13-26, dated April 30, 2013

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-13-3704 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-13-3704 and should be addressed to James A. Gresham, Manager, Regulatory Compliance, Westinghouse Electric Company, Suite 428, 1000 Westinghouse Drive, Cranberry Township, Pennsylvania 16066.

Very truly yours,

James A. Gresham, Manager
Regulatory Compliance

Enclosures

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared James 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:

James A. Gresham, Manager
Regulatory Compliance

Sworn to and subscribed before me
this 30th day of April 2013

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-13-26 P-Attachment, "Supplemental Information on End-of-Life Seismic/LOCA calculations for the AP1000 Pressurized Water Reactor" (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter, LTR-NRC-13-26, 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 the review of WCAP-17524, and may be used only for that purpose.

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

(a) Obtain NRC approval of the **AP1000**® Pressurized Water Reactor (PWR) Advanced First Core, as documented in WCAP-17524, "AP1000 Core Reference Report".

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of the information to its customers for the purpose of assisting customers in obtaining license changes for the **AP1000** PWR.

(b) This document establishes a portion of the licensing basis for the **AP1000** PWR.

(c) 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 technical evaluation justifications 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

Supplemental Information on End-of-Life Seismic/LOCA calculations for the AP1000 Pressurized Water Reactor (Non-Proprietary)

April 2013

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

1.0 INTRODUCTION

This report provides supplemental information to the **AP1000**® Core Reference Report (Reference 1) to address issues related to fuel assembly seismic structural response described in the NRC letter accepting this topical report for review (Reference 2). Specifically, the acceptance letter states:

> *"Fuel Assembly Seismic Structural Response – The Topical Report indicates (see Section 4.2.3.5) that the fuel assembly seismic response analysis follows the guidelines of Appendix A of the Standard Review Plan, Section 4.2, which may imply that only the beginning of life (BOL) condition of grid strength is needed for seismic and LOCA evaluations. Because of spacer grid spring relaxation due to irradiation which could affect the fuel bundle stiffness and the grid strength, the NRC staff has determined the need to evaluate the fuel structural response to the seismic/LOCA load for the minimum grid strength considering irradiation effects."*

To address this issue, Westinghouse has provided responses to three related RAIs (24, 25, & 27) in References 3 & 4 and performed end-of-life (EOL) tests and analyses. Basically, these tests and analyses are a repeat of the beginning-of-life (BOL) tests and analyses considering EOL effects. The RAI responses and the EOL tests and analyses are described in this report. The results demonstrate continued satisfaction of the acceptance criteria considering end-of-life (EOL) conditions.

Testing was performed to determine the grid strength and the fuel assembly dynamic characteristics at EOL conditions. The dynamic analyses to determine the EOL grid impact loads were performed using models and methods consistent with the BOL models and methods considering grid and fuel assembly properties and characteristics determined from the EOL tests. In addition, increased fuel assembly damping was used in the EOL core dynamic analysis compared to the damping value used in the BOL analysis. Justification for the fuel assembly damping value used in the EOL analysis is provided in this report and in the RAI responses.

2.0 GRID STRENGTH AT EOL

To determine the EOL strength of the grids, impact tests were performed using **AP1000** mid grids with gaps between the grid springs and the fuel rods as described in the response to RAI 25 (Reference 3). Gaps that form between the grid springs and the fuel rods are the primary contributor to the reduction in grid strength that occurs at EOL conditions. Gap formation is due to irradiation induced spring relaxation, grid growth, and cladding creep-down. Except for the gaps, these tests were performed using the standard Westinghouse grid impact testing methodology. This is the same methodology that was used for the original BOL **AP1000** grid impact tests.

The average gap used in the **AP1000** EOL impact tests conservatively exceeds the upper [ ]a,c confidence level of the mean gap based on post-irradiation exam (PIE)

measurements of grid cell size and fuel rod diameter as shown in Figure 1 below. These PIE measurements are from fuel assemblies with burn-ups comparable to the **AP1000** EOL burn-ups and with fuel rods with the same diameter and material as the **AP1000** fuel rods. These fuel assemblies have RFA style grids. The RFA design is the basis for the **AP1000** mid grid design. The RFA grids have the same material (ZIRLO®) and strap thicknesses as the **AP1000** grids. **[**

]a,c

a,c

Figure 1. Grid Spring to Fuel Rod Gaps at EOL Conditions from PIE Measurements

[

]a,c

The general grid impact test set-up includes a swinging hammer mounted on a four bar linkage, supporting back plates, load cells, angular transducer, furnace, thermocouples, and mounting fixtures. Two different supporting backing plates are used – one to represent impact between grids, and one to represent impact between the grid and the core barrel shroud.

The hammer is released from various increasing angular displacements resulting in increasing grid impact loads until failure of the grid occurs. Failure is characterized as a reduction in the impact load during testing. [

]a,c A picture of a typical failed EOL grid is shown in Figure 2. [

]a,c

a,c

[ ]

Figure 2. Typical EOL Grid Failure Mode

The grid strength is defined as the lower 95% confidence level of the mean failure load. A summary of the results is provided in Table 1. [

]a,c

Table 1. Summary of Grid Impact Test Results

a,c

[ ]

These results are based on impact tests of the mid grid which is the grid with the highest seismic loading and lowest margins. Additional impact testing of the **AP1000** IFM grids at EOL conditions is not necessary because the IFM grids have a [ ]a,c. As such, the difference between the BOL and the EOL grid strength is expected to be minimal. Furthermore, the strength of the IFM grid is significantly greater than the maximum IFM grid impact load providing sufficient margin [ ]a,c to accommodate any minor EOL effects.

3.0 FUEL ASSEMBLY MODAL FREQUENCIES AT EOL

The **AP1000** fuel assembly described in the Core Reference Report (Reference 1) was tested to determine the assembly EOL modal frequencies. The EOL modal frequencies are lower than the BOL frequencies and result in higher grid impact loads. These frequencies are used to develop the core dynamic analysis models. To simulate EOL conditions the assembly was tested with gapped grid cells; i.e., a clearance between the grid springs and the fuel rods. The mid grid gaps were similar to the gaps used in the EOL grid impact tests. Except for the gaps, these tests were performed using the standard Westinghouse fuel assembly vibration test methodology, which is the same methodology used for BOL tests. Results from the EOL vibration test comparing the BOL and EOL fuel assembly frequencies is summarized Table 2. Based on these test results the first mode frequency at EOL is [ ]^{a,c}.

Table 2. Fuel Assembly Modal Frequencies a,c

[

]

4.0 FUEL ROD STIFFENING AT EOL

At EOL conditions the fuel rod bending stiffness is increased due to bonding that occurs between the pellet and cladding because of cladding creep down and pellet swelling. Increased fuel rod bending stiffness will offset some of the reduction in the fuel assembly lateral vibration frequencies due to gap formation between the grid springs and the fuel rods. Reduced fuel assembly frequencies result in higher seismic grid impact loads.

[

]^{a,c}

[

]a,c

a,c

Figure 3. Irradiated Fuel Rod Four Point Bend Test

5.0 FUEL ASSEMBLY DAMPING

The BOL core dynamic analysis was performed using a conservative fuel assembly damping ratio of [ ]a,c. To maintain acceptable grid impact load margins at EOL conditions, higher (more realistic) damping must be considered in the EOL analysis. Justification for higher damping was provided in the responses to RAIs 24 & 27 (References 3 & 4) based on considerations of flowing water effects as discussed below.

Figures 4 and 5 summarize Westinghouse fuel assembly damping test data in air, still water and flowing water for water temperatures between 80°F and 300°F. The test data provides a direct comparison of the damping values due to the different media. These tests are described in Reference 5. An analysis of this data leads to the following observations of the trends associated with damping in flowing water:

1) Damping in flowing water increases slightly with vibration amplitude.
2) Damping in flowing water decreases slightly with increasing temperature.
3) Flow velocity has a strong effect on damping and results in a significant increase in damping with increasing flow velocity.

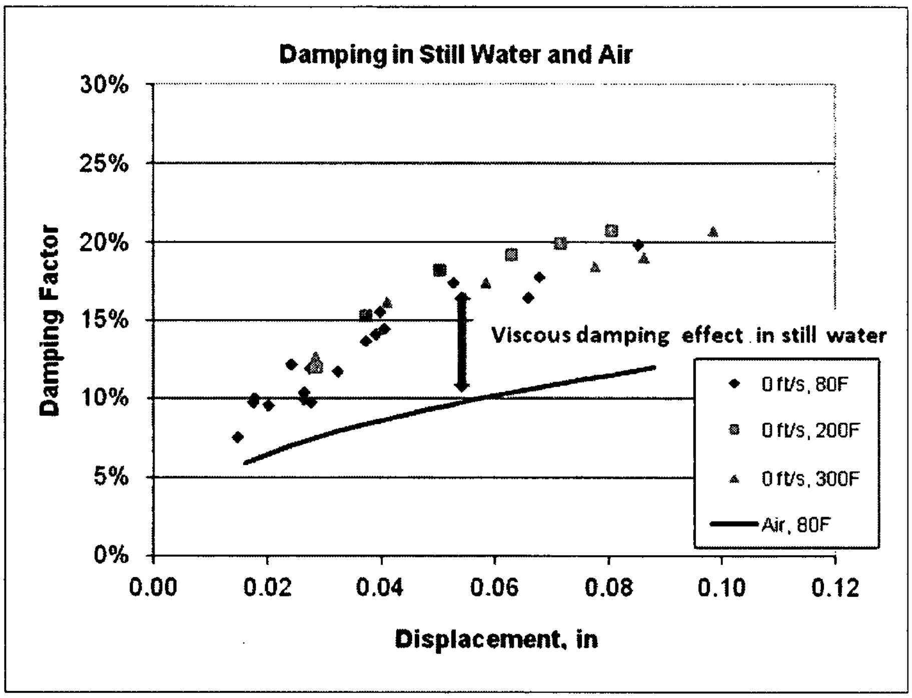

Figure 4. Fuel Assembly Damping Factors in Air and Still Water – Westinghouse Test Data

a,c

[ ]

Figure 5. Fuel Assembly Damping in Flowing and Still Water – Westinghouse Test Data

These observations are consistent with other test results that are available publicly (References 6 and 7). The considerations for application of hydraulic damping coefficients due to flowing water are discussed further below.

Fuel assembly damping force in flowing water is actually the summation of fuel structural damping in air (due to material and friction damping), viscous damping in still water and hydraulic damping in flowing water as shown in Equation (1). All three damping coefficients are non-linear.

$$F_d = c_s\dot{x} + c_v\dot{x} + c_h\dot{x} \tag{1}$$

c_s – Structural damping coefficient in air, mainly increasing with amplitude
c_v – Viscous damping in still water, mainly increasing with vibration velocity
c_h – Hydraulic damping in flowing water, mainly increasing with axial flow velocity

Flow Rate Dependence

Both structural damping and viscous damping terms are vibration-amplitude dependent and increase with vibration amplitude. The hydraulic damping term in flowing water is flow rate dependent and it dominates the total damping. Typical fuel assembly displacements during a seismic event with grid impact occurrences are much greater than [ ][a,c]. Therefore, the damping data from the flowing water tests with vibration displacements greater than [ ][a,c] (see green box in Figure 5) are used to obtain the best fit curve of damping versus flow velocity shown in Figure 6.

a,c

Figure 6. Fuel Assembly Damping in Flowing Water

Temperature, Vibration Amplitude, and Measurement Variability Effects

The data variability shown in Figure 6 is due to variations in amplitude, temperature [ ][a,c] and measurement. This data is bounded [ ][a,c] as shown in Figure 7. The lower bound curve is approximately [ ][a,c] below the best fit curve and conservatively covers measurement variability and temperature effects up to [ ][a,c]. The lower bound curve is conservative because the

confidence interval was determined based on data variability that includes variations in amplitude between [ ][a,c]. Typical fuel assembly displacements during a seismic event with grid impact occurrences are much greater than [ ][a,c]. If only higher amplitude data is considered, the best fit curve would be higher and the lower bound curve would be closer to the best fit curve. It is observed that the lower bound curve covers all test data points except one at high flow rate, [ ][a,c].

a,c

Figure 7. Statistical Evaluation of Damping Data

As shown in Figure 5, damping is not very sensitive to temperature. For example, [ ][a,c]. This is consistent with data from Reference 7 where it was concluded that in the range between 70° to 600°F "damping is minimally affected by temperature in water." To account for temperatures up to [ ][a,c], the lower bound damping curve is conservatively reduced by an additional [ ][a,c] as shown in Figure 8.

a,c

Figure 8. Damping Design Curve

The design damping curve is defined [ ]^{a,c} below the best fit curve. This conservatively envelops the combined effects of measurement uncertainty and temperature up to [ ]^{a,c}. It should be noted that a [ ]^{a,c} reduction in the damping coefficient corresponds to approximately a [ ]^{a,c} reduction in the damping coefficient [ ]^{a,c}.

The damping in flowing water is the summation of structural damping, viscous damping and hydraulic damping as shown in Equation (1). The damping curves in Figure 8 show the tendency of damping to increase with flow rate. Based on Equation (1), the damping at 0 ft/s should be equal to the damping in still water; however, extrapolation of the damping design curve to a flow velocity of 0 ft/s results in a damping coefficient of [ ]^{a,c}. As such, the design damping curve is conservative, because the damping coefficient in still water (flow velocity = 0 ft/s) is [ ]^{a,c}.

Effect of Design Uncertainty on Damping in Flowing Water

The fuel assembly used in the Westinghouse flowing water damping tests was a PWR fuel assembly [ ]^{a,c}. Although the array size, number of thimbles, and number of mid grids vary among fuel assembly designs, the basic structure of this test assembly is similar to all other PWR fuel assemblies including the **AP1000** fuel assembly. The Westinghouse test data provides a direct comparison and clearly shows the differences of damping values due to the different media (air, still water, and flowing water).

Other fuel vendors have also performed fuel assembly damping tests with similar but not identical PWR fuel assemblies to the Westinghouse test fuel assembly. The test assembly from Reference 6 has a 17x17 array, 8 mid grids and 264 fuel rods with 0.374 inch OD. These parameters are the same as for the **AP1000** fuel assembly. Reference 6 provides similar damping values and demonstrates similar damping characteristics such as (1) the damping values in air and still water are amplitude dependant and (2) the damping in flowing water is significantly higher than in air and still water and is less amplitude dependant. The test assembly from Reference 7 also has a 17x17 array and 264 fuel rods with 0.374 inch OD and also provides similar damping values. The main reason why fuel assembly damping coefficients obtained from tests of different designs are similar is because of the geometric similarity of the various designs. All of these fuel assemblies are comprised of a square array of fuel rods with guide thimble tubes and spacer grids. For this reason Westinghouse currently uses the same damping coefficient for all types of Westinghouse fuel in Westinghouse type reactors.

Comparisons of the deltas between in-air and flowing water damping among various fuel assembly designs are provided in Table 3. This data shows that the deltas among the designs are very similar. By comparing the deltas, the uncertainties from the various tests are minimized and the effects of flowing water are emphasized.

The deltas between in-air and flowing water damping, shown in Table 3, exclude the fuel assembly mechanical damping in air. By adding a conservative mechanical damping of

[ ]^{a,c} to any of the damping values in Table 3, the damping in flowing water will be greater than [ ]^{a,c}, which is the damping from the design curve at [ ]^{a,c}. It should be noted that the **AP1000** fuel assembly mechanical damping in air at EOL conditions is [ ]^{a,c}. Therefore, the damping design curve is conservative and no additional reductions are necessary to account for differences between the tested fuel assembly design and the **AP1000** fuel assembly design.

Table 3*. Delta between Flowing Water (FW) and In-Air Damping **a,c**

[ ]

<u>Pump Coastdown</u>

[

]^{a,c}

a,c

[ ]

Figure 9. RCS Pump Coastdown

The damping coefficient as a function of time during a pump coastdown is shown in Figure 10. This Figure was generated using the damping design curve from Figure 8 and the pump coastdown curve from Figure 9 assuming the Technical Specification minimum flow at the start of the coastdown. [ ][a,c] This is the damping value that is used in the core dynamic seismic analysis.

a,c

[ ]

Figure 10. Damping during RCP Coastdown

It should be noted that damping is a cumulative effect for dissipating vibration energy over time. [ ]^{a,c} As such, using [ ]^{a,c} damping in the seismic analysis is conservative.

6.0 EOL SEISMIC/LOCA ANALYSIS

The BOL core dynamic analysis models were updated based on data from the EOL grid impact tests and fuel assembly mechanical tests. These updated models were used to perform the EOL fuel assembly seismic/LOCA analysis. A damping value of [ ]^{a,c} was used in the seismic analysis. The LOCA analysis was conservatively performed assuming [ ]^{a,c} damping.

The dominant grid impact loads occur during a seismic event. The LOCA grid impact loads are negligible. This is because the main reactor coolant pipes in an **AP1000** plant are qualified for leak-before-break. Results from the analysis indicate that the limiting grid impact load is [ ]^{a,c}. The EOL grid strength is [ ]^{a,c} resulting in a margin of [ ]^{a,c}. Therefore, requirements for control rod insertability are met.

These results are conservative. They are based on a generic bounding seismic spectrum considering various soil conditions. The site specific seismic spectrum at any individual **AP1000** site is expected to be less limiting. In addition, the fuel assembly dynamic models don't consider [ ]^{a,c} If these effects were included, it is expected that grid impact loads would be less.

To insure fuel rod fragmentation does not occur, additional EOL seismic cases were run with [ ]^{a,c} damping. Results from these cases demonstrate that the limiting fuel rod stress [ ]^{a,c} remains significantly below the allowable limit [ ]^{a,c}.

Analysis of operating basis earthquake (OBE) loads is not required according to the DCD (Tier 2, Section 3.7 of Reference 8); however, to insure that no grid deformation occurs during an OBE, an evaluation of OBE loads was performed. Typically, OBE analyses are performed assuming the plant is operating at full power conditions; however, in this case the evaluation was conservatively performed assuming no flow [ ]^{a,c}. The OBE is one-third of the SSE in accordance with the DCD (Tier 2, Section 3.7 of Reference 8). [ ]^{a,c} As such, no grid deformation is expected during an OBE.

7.0 SUMMARY AND CONCLUSIONS

Results demonstrate that the limiting combined seismic and LOCA grid impact loads are less than the grid strength at EOL conditions [ ]^{a,c}.

The EOL strength of the grids was determined from impact tests performed on **AP1000** grids with gaps between the grid springs and the fuel rods. Gap formation between the grid springs and the fuel rods due to irradiation induced spring relaxation, grid growth, and cladding creep-down is the primary contributor to the reduction in grid strength that occurs at EOL conditions.

The grid impact loads were determined from core dynamic analyses. The analytical models in these analyses were adjusted for EOL effects based on properties obtained from the EOL grid impact tests and the EOL fuel assembly mechanical test. To simulate EOL conditions, the fuel assembly mechanical test was performed with gapped grid cells; i.e., a clearance between the grid springs and the fuel rods.

The seismic loads were calculated based on a fuel assembly damping coefficient of [ ]^{a,c}. This damping coefficient is based on Westinghouse test data considering hydraulic damping due to flowing water effects. The flow velocity used to determine the damping coefficient conservatively assumed that the RCS pumps would trip at the start of the seismic event and that the flow rate at the beginning of the pump coastdown is equal to the Technical Specification minimum flow. The Westinghouse damping data is consistent with test data reported by others. The Westinghouse data was conservatively adjusted for temperature effects and measurement uncertainty. The effect of design differences between the tested fuel assembly and the **AP1000** fuel assembly were judged to be minor based on a review of test data from various designs.

REFERENCES

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2. Tonacci, M., "Acceptance for Review of Westinghouse Topical Report WCAP-17524-P, Revision 0, **AP1000** Core Reference Report," ML12144A201, June 5, 2012, U.S. Nuclear Regulatory Commission.

3. Gresham, J.A., "Westinghouse Response to NRC RAIs on WCAP-17524, **AP1000** Core Reference Report (Proprietary/Non-Proprietary)," LTR-NRC-12-86, January 2, 2013, Westinghouse Electric Company LLC.

4. Gresham, J.A., "Second Transmittal of Westinghouse Responses to NRC RAIs on WCAP-17524, **AP1000** Core Reference Report (Proprietary/Non-Proprietary)," LTR-NRC-13-3, January 10, 2013, Westinghouse Electric Company LLC.

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8. Westinghouse **AP1000** Design Control Document, Rev 19, ML11171A500, June 2011.