Enclosure 2

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GEH Licensing Topical Report (LTR)
"ESBWR Steam Dryer – Plant Based Load Evaluation Methodology,"
NEDO-33408, Revision 1 – Public Version

HITACHI

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Licensing Topical Report

ESBWR STEAM DRYER -
PLANT BASED LOAD EVALUATION METHODOLOGY

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IMPORTANT NOTICE REGARDING THE CONTENTS OF THIS REPORT

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Acronyms and Abbreviations

BWR	Boiling Water Reactor
CAD	Computer-Aided Design
CLTP	Current Licensed Thermal Power
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
DOE	Design Of Experiments
EPU	Extended Power Uprate
ESBWR	Economic Simplified Boiling Water Reactor
FE / FEM	Finite Elements / Finite Element Method / Finite Element Model
FRF	Frequency Response Function
GDC	General Design Criteria
GEH	GE Hitachi Nuclear Energy
Hz	Hertz
LTR	Licensing Topical Report
MSL	Main Steam Line
OLTP	Original Licensed Thermal Power
NRC	Nuclear Regulatory Commission
PBLE	Plant Based Load Evaluation
PSD	Power Spectral Density
PT	Pressure Transducer
PWR	Pressurized Water Reactor
QC2	Quad Cities 2
RG	Regulatory Guide
RPV	Reactor Pressure Vessel
SF	Singularity Factor
SRSS	Square Root of the Sum of the Squares

SRV	Safety / Relief Valve
3D	Three Dimensional

Abstract

A methodology, termed Plant Based Load Evaluation (PBLE), is presented for defining the fluctuating loads that are imposed upon the Economic Simplified Boiling Water Reactor (ESBWR) reactor steam dryer. The PBLE load definition can be applied to a structural finite element model of the steam dryer in order to determine the steam dryer alternating stresses.

1.0 INTRODUCTION

As a result of steam dryer issues at operating Boiling Water Reactors (BWRs), the US Nuclear Regulatory Commission (NRC) has issued revised guidance concerning the evaluation of steam dryers [1]. Analysis must show that the dryer will maintain its structural integrity during plant operation due to acoustic and hydrodynamic fluctuating pressure loads. This demonstration of steam dryer structural integrity comes in three steps:

(1) Predict the fluctuating pressure loads on the dryer,

(2) Use these fluctuating pressure load in a structural analysis to qualify the steam dryer design

(3) Implement a startup test program for confirming the steam dryer design analysis results as the plant performs power ascension.

The PBLE (Plant Based Load Evaluation) is an analytical tool developed by GEH to perform the prediction of fluctuating pressure loads on the steam dryer. This report provides the theoretical basis of the PBLE method that will be applied for determining the fluctuating loads on the ESBWR steam dryer, describes the PBLE analytical model, determines the biases and uncertainties of the PBLE formulation and describes the application of the PBLE method to the evaluation of the ESBWR steam dryer.

2.0 MODEL DESCRIPTION

2.1 Overview

[[ ]]

Figure 1. PBLE Process Flow

The PBLE can be [[ ]] This is the methodology to be used in the ESBWR evaluation and is described in this report. [[ ]]

The PBLE is built on the commercial software packages Matlab [2] and Sysnoise[3]. Matlab is a software package designed for engineering computations. The general architecture of the PBLE scripts makes use of the Matlab programming language and graphical interface.

The vessel acoustic response is calculated with Sysnoise. Sysnoise is a program for modeling acoustic wave behavior in fluids, using implementations of the finite element and boundary element methods. In the PBLE context, Sysnoise calculates how sound waves propagate through a FEM model of the RPV dome steam volumes. This 3D acoustic model is described in detail in Section 2.2 below.

2.2 Dome Acoustic Model

2.2.1 Sysnoise Modeling Principles

Sysnoise [3] models acoustics as a wave-phenomenon. The modeling is carried out in the frequency domain, thus using the so-called Helmholtz form of the wave equation (see e.g. [5] and [10]). [[

]] The following system of equations is solved:

$$\text{(1)} \quad \left[K + i\omega C - \omega^2 M\right]\{p\} = \{F_A\}$$

Where F_A is the vector of nodal acoustic forces, proportional to the normal velocity boundary conditions imposed on the faces of the mesh. The stiffness *[K]*, damping *[C]* and mass *[M]* matrices are computed at each frequency. The system of equations is thus set up and solved to obtain the pressure distribution *{p}*. The velocity field is obtained by differentiation of the pressure field at the Gauss points of the elements and then extrapolation and averaging at the nodes.

2.2.2 Geometry Modeling

The dome FE mesh (Figure 2) comprises all RPV steam volumes [[
]]

In all GEH BWRs, there are two steam zones with different steam qualities, upstream and downstream of the dryer. [[

]]

[[ ]]

Figure 2. Modeled steam region (left) and details of typical vessel meshes (right)

[[ ]]

Figure 3. Vessel response (left) [[ ]]

[[

]]

[[ ]]

Figure 4. First typical [[

]]

Table 1 First Ten RPV modes

Mode No.	Modal Frequency (Hz)
1	[[
2	
3	
4	
5	
6	
7	
8	
9	
10	]]

2.2.3 Finite Element Model

[[

]]

[[ ]]

Figure 5. [[ ]]

[[

]]

[[ ]]

Figure 6. [[ ]]

[[

]]

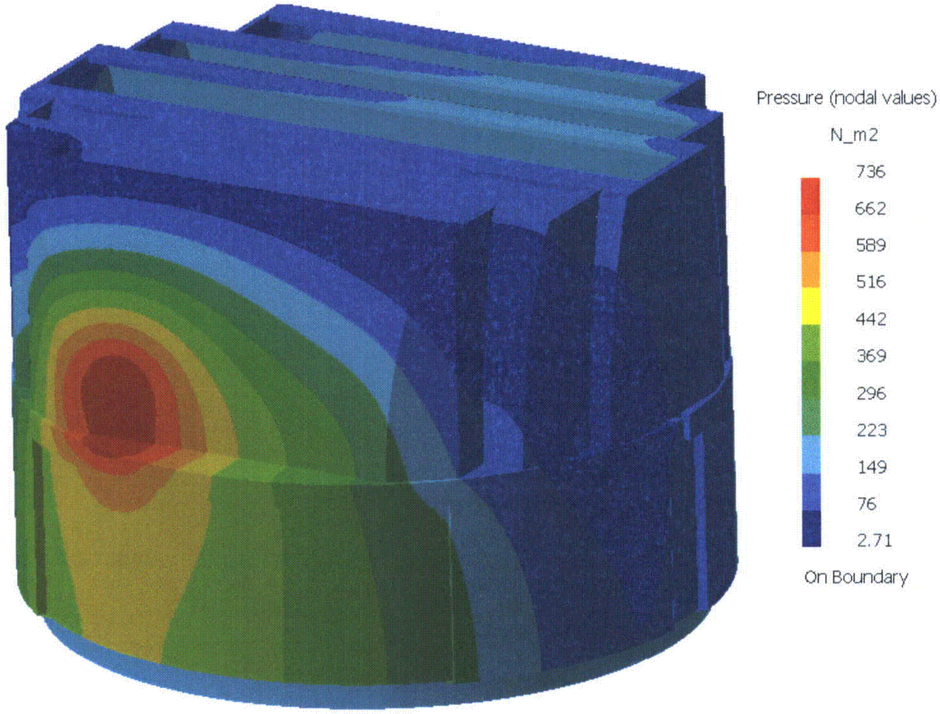

Figure 7. Pressure amplitudes on dryer at 15 Hz (Forced Response)
View of CD side

2.2.4 Fluid Properties and Boundary Conditions

[[

]]

Steam and water properties including impedance boundary conditions are described in detail in Section 2.4.

[[ ]]

Figure 8. Vessel passive boundary conditions

2.3 PBLE from [[ ]]

2.3.1 Solution Formulation

The pressure at any dryer point P [[

]] as shown in the benchmark assessments in Sections 3.2 and 3.3 of this report.

[[

]]

These considerations make the PBLE from in-vessel pressures a quite powerful tool.

2.3.2 Singularity Factor

The Singularity Factor (SF) is a tool to understand the mathematical limitations in PBLE. It is calculated as: [[

]]

[[ ]]

Figure 9. [[ ]]

2.4 Steam and Water Acoustic Properties

This section describes all steam and water characteristic properties used in PBLE models: [[

]]

Dry steam properties, including speed of sound and density, are readily known from standard steam tables published by the International Association for the Properties of Water and Steam [6]. Petr [7] developed the [[

]] by Karplus [8].

2.4.1 [[ ]]

The following summary follows the description given in [7], Section 2. The variable nomenclature for this section is in Table 2.

[[

]]

Table 2 [[ ]]

[[	
	]]

[[

]]

[[ ]]

Figure 10. [[ ]]

2.4.2 Steam-water interface

[[

]]

[[ ]]

Figure 11. Steam-Water Interfaces

Table 3 Impedances in a Typical BWR RPV Environment

[[				
				]]

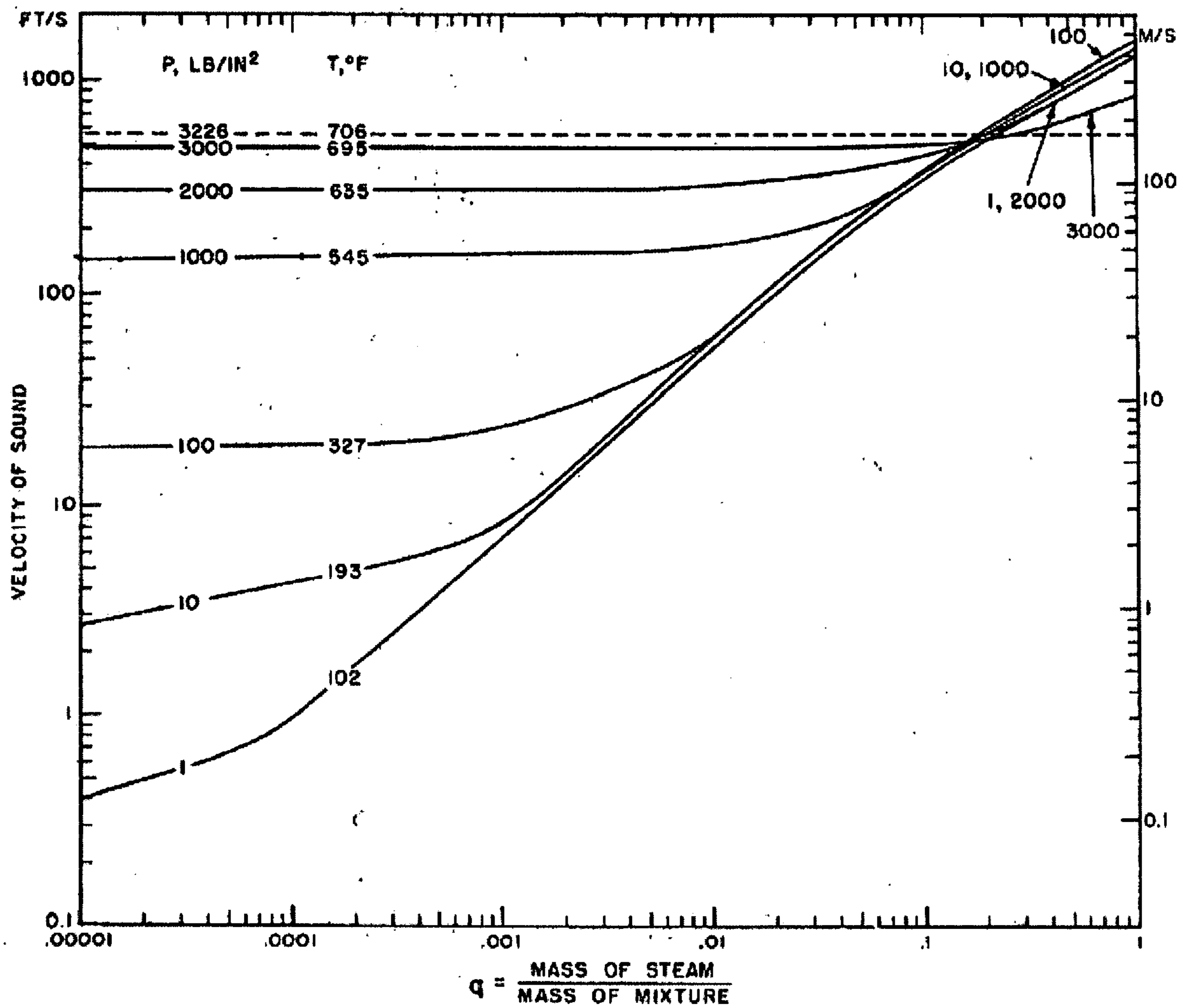

Figure 12. Speed of sound in [[ ]] (Fig. 5 in Karplus [8])

The solution that was adopted for the PBLE is to model [[

]]

3.0 MODEL QUALIFICATION: BWR PLANT VALIDATION

The Quad Cities Unit 2 (QC2) replacement steam dryer, installed in 2005, was the first GEH BWR unit instrumented with a significant number of on-dryer pressure sensors. This section presents the steam dryer fluctuating load definitions obtained with the PBLE at QC2 for two power levels, one at the QC2 Original Licensed Thermal Power (OLTP) level and at Extended Power Uprate (EPU) conditions.

3.1.1 Procedure for QC2 benchmarks

The QC2 dryer instrumentation comprised 27 PT sensors, labeled P:1 through P:27 [9]. Pressure sensor P:26, which was installed on the stream dryer temporary instrumentation mast, is not considered in this benchmark since the main interest is in pressure on the dryer surface. [[

]]

[[ ]]

Figure 13. Sensor Positions for Dryer Data Benchmark

[[

]]

Table 4 QC2 Frequency Bands for Main Acoustic Peaks

OLTP		EPU	
Begin Frequency (Hz)	End Frequency (Hz)	Begin Frequency (Hz)	End Frequency (Hz)
8	10	8	10
13	16	13	16
22	26	22	26
29	31	28	34
32	35	38	46
44	48	48	58
61	69	132	145
130	136	146	153
137	142	154	158
147	149	159	168
150	153	146	158
154	158		
150	158		

[[

]] The last segment PSDs at all sensors locations are plotted in Appendix A and Appendix B.

3.2 QC2 Benchmark at OLTP

3.2.1 From [[ ]]

[[ ]]

Figure 14. [[ ]]
(Numbers in parenthesis refer to the equation numbers)

3.2.2 From [[ ]]

[[ ]]

Figure 15. [[ ]]

3.3 QC2 Benchmark at EPU

3.3.1 From [[ ]]

[[ ]]

Figure 16. QC2 EPU Benchmark from [[ ]]

3.3.2 From [[ ]]

[[ ]]

Figure 17. QC2 EPU Benchmark from [[ ]]

3.4 QC2 Benchmark Conclusions

The PBLE predictions using [[ ]] are highly accurate: the low frequency content below [[ ]] These good results validate the main assumption that [[ ]] to reproduce measured dryer pressures, including at low frequencies.

Using [[ ]] is on the conservative side. [[ ]] This demonstrates the [[ ]].

The main limitations in these dryer data benchmark lie within the FE model. [[ ]] at both power levels.

The modeling of the region inside the dryer is also challenged; [[ ]] are generally less accurate.

Overall the PBLE from [[ ]] emerges as a viable tool for developing dryer load definitions. The frequency content and the spatial distribution are well matched, the amplitude predictions are generally conservative and pressures away from the MSL nozzles are consistent with plant test data from other dryers.

4.0 APPLICATION METHODOLOGY

4.1 Scope of Application and Licensing Requirements

4.1.1 Scope of Application

The scope of the application for the Plant Based Load Evaluation Licensing Topical Report is to provide a methodology for determining the fluctuating pressure loads that the ESBWR steam dryer will experience during normal operation. This fluctuating load definition can then be applied to a finite element model of the ESBWR steam dryer in order to determine the structural qualification of the dryer.

4.1.2 Specific Licensing Requirements

Plant components, such as the steam dryer in a BWR nuclear power plant, perform no safety function but must retain their structural integrity to avoid the generation of loose parts that might adversely impact the capability of other plant equipment to perform their safety function. Potential adverse flow effects must be evaluated for the steam dryer to meet the requirements of GDC 1 and 4 in Appendix A of 10 CFR Part 50.

Standard Review Plan [12], Section 3 requires that the dynamic responses of structural components with the reactor vessel caused by steady-state and operational flow transient conditions should be analyzed for prototype (first of a design) reactors. The analytical assessment of the vibration behavior of the steam dryer includes the definition of the input-forcing function including bias errors and uncertainty. References [12] and [13] contain specific acceptance criteria related to formulating forcing functions for vibration prediction. Reference 1 provides guidance on acceptable methods for formulating the forcing functions for vibration prediction.

4.2 Proposed Application Methodology

The PBLE method for formulating the forcing function for vibration prediction for the ESBWR steam dryer is in conformance with the guidance contained in Regulatory Guide 1.20 Revision 3.

4.2.1 Conformance with Regulatory Guide 1.20 Rev 3

The following table provides the conformance of the PBLE to the requirements contained in Section 2.1 of Regulatory Guide 1.20 Revision 3 [1].

RG 1.20 Section	Criteria	PBLE Conformance
2.1.(1)(a)	Determine the pressure fluctuations and vibration in the applicable plant systems under flow conditions up to and including the full operating power level. Such pressure fluctuations and vibration can result from hydrodynamic effects and acoustic resonances under the plant system fluid flow conditions.	Acceptable -The PBLE method is applicable up to the full power level of the plant. Since the PBLE approach in this LTR uses [[ ]], all pressure fluctuation, either hydrodynamic or acoustic are captured.
2.1.(1)(b)	Justify the method for determining pressure fluctuations, vibration, and resultant cyclic stress in plant systems. Based on past experience, computational fluid dynamics (CFD) analyses might not provide sufficient quantitative information regarding high-frequency pressure loading without supplemental analyses. Scale testing can be applied for the high-frequency acoustic pressure loading and for verifying the pressure loading results from CFD analyses and the supplemental analyses, where the bias error and random uncertainties are properly addressed.	The justification of the PBLE method is acceptable based on the benchmarking shown in Section 4.5 of this report. Stress analysis is not applicable to the scope of this LTR. CFD modeling is not applicable to the PBLE
2.1.(1)(c)	Address significant acoustic resonances that have the potential to damage plant piping and components including steam dryers, and perform modifications to reduce those acoustic resonances, as necessary, based on the analysis.	Acceptable – the PBLE is capable of determining acoustic resonances that may be detrimental to the steam dryer. Modifications for reducing acoustic resonances is beyond the scope of this LTR
2.1.(1)	Scale Model Testing	Not applicable - Scale model Testing is not used in the PBLE for determination of the steam dryer loads
2.1.(1)	Computational Fluid Dynamic (CFD) modeling	Not applicable - CFD modeling is not used in the PBLE for determination of the steam dryer loads

RG 1.20 Section	Criteria	PBLE Conformance
2.1.(2)	Describe the structural and hydraulic system natural frequencies and associated mode shapes that may be excited during steady-state and anticipated transient operation, for reactor internals that, based on past experience, are not adversely affected by the flow-excited acoustic resonances and flow-induced vibrations. Additional analyses should be performed on those systems and components, such as steam dryers and main steam system components in BWRs and steam generator internals in PWRs, that may potentially be adversely affected by the flow-excited acoustic resonances and flow-induced vibrations. These additional analyses are summarized below.	Acceptable - The PBLE is capable of determining the acoustic mode shapes within the reactor steam dome. It will simulate the acoustic response of the steam dome from the significant excitation sources.
2.1.(2)	Determine the damping of the excited mode shapes, and the frequency response functions (FRFs, i.e., vibration induced by unit loads or pressures, and stresses induced by unit loads or pressures), including all bias errors and uncertainties.	Acceptable – FRF are determined by the PBLE. Bias errors and uncertainties have been addressed.
2.1.(3)	Describe the estimated random and deterministic forcing functions, including any very-low-frequency components, for steady-state and anticipated transient operation for reactor internals that, based on past experience, are not adversely affected by the flow-excited acoustic resonances and flow-induced vibrations. Additional analyses should be performed on those systems and components, such as steam dryers and main steam system components in BWRs and steam generator internals in PWRs, that may potentially be adversely affected by the flow-excited acoustic resonances and flow-induced vibrations. These additional analyses are summarized below.	Acceptable – the PBLE is capable of determining the forcing functions in the frequency range important to BWR dryers.
2.1.(3)	Evaluate any forcing functions that may be amplified by lock-in with an acoustic and/or structural resonance (sometimes called self-excitation mechanisms). A lock-in of a forcing function with a resonance strengthens the resonance amplitude. The resulting amplitudes of the forcing function and resonance response can therefore be significantly higher than the amplitudes associated with non-lock-in conditions.	Lock in assessment is not required for PBLE loads [[ ]]

RG 1.20 Section	Criteria	PBLE Conformance
2.1.(3)	The applicant/licensee should determine the design load definition for all reactor internals, including the steam dryer in BWRs up to the full licensed power level, and should validate the method used to determine the load definitions based on scale model or plant data. BWR applicants should include instrumentation on the steam dryer to measure pressure loading, strain, and acceleration to confirm the scale model testing and analysis results. BWR licensees should obtain plant data at current licensed power conditions for use in confirming the results of the scale model testing and analysis for the steam dryer load definition prior to submitting a power uprate request.	Acceptable – The PBLE uses in plant data for the determination of the steam dryer load definition.
2.1.(3)	In recent BWR EPU requests, some licensees have employed a model to compute fluctuating pressures within the RPV and on BWR steam dryers that are inferred from measurements of fluctuating pressures within the MSLs connected to the RPV. Applicants should clearly define all uncertainties and bias errors associated with the MSL pressure measurements and modeling parameters. The bases for the uncertainties and bias errors, such as any experimental evaluation of modeling software, should be clearly presented. There are many approaches for measuring MSL pressures and computing fluctuating pressures within the RPV and the MSLs. Although some approaches reduce bias and uncertainty, they still have a finite bias and uncertainty, which should be reported. Based on historical experience, the following guidance is offered regarding approaches that minimize uncertainty and bias error:	Acceptable – the PBLE methodology in this report uses [[ ]] for determination of the load definition. The PBLE methodology in this report demonstrates the methodology to determine bias errors and uncertainties associated with the PBLE methodology [[ ]].
2.1.(3)(a)	At least two measurement locations should be employed on each MSL in a BWR. However, using three measurement locations on each MSL improves input data to the model, particularly if the locations are spaced logarithmically. This will reduce the uncertainty in describing the waves coming out of and going into the RPV. Regardless of whether two or three measurement locations are used, no acoustic sources should exist between any of the measurement locations, unless justified.	Not applicable – the PBLE methodology in this report [[ ]].

RG 1.20 Section	Criteria	PBLE Conformance
2.1.(3)(b)	Strain gages (at least four gages, circumferentially spaced and oriented) may be used to relate the hoop strain in the MSL to the internal pressure. Strain gages should be calibrated according to the MSL dimensions (diameter, thickness, and static pressure). Alternatively, pressure measurements made with transducers flush-mounted against the MSL internal surface may be used. The effects of flow turbulence on any direct pressure measurements should be accounted for in a bias error and uncertainty estimate.	Not applicable – the PBLE uses [[ ]] The effects of flow turbulence on the pressure measurement is included in the PBLE uncertainty assessment.
2.1.(3)(c)	The speed of sound used in any acoustic models should not be changed from plant to plant, but rather should be a function of temperature and steam quality.	Acceptable – the speed of sound in the PBLE is a function of the steam fluid conditions within the RPV.
2.1.(3)(d)	Reflection coefficients at any boundary between steam and water should be based on rigorous modeling or direct measurement. The uncertainty of the reflection coefficients should be clearly defined. Note that simply assuming 100-percent reflection coefficient is not necessarily conservative.	Acceptable – the conditions of the steam water interface and the associated uncertainty is developed for the PBLE method.
2.1.(3)(e)	Any sound attenuation coefficients should be a function of steam quality (variable between the steam dryer and reactor dome), rather than constant throughout a steam volume (such as the volume within the RPV).	Acceptable – the PBLE formulation uses the steam quality in the reactor steam dome and dryer for the sound attenuation coefficients.
2.1.(3)(f)	Once validated, the same speed of sound, attenuation coefficient, and reflection coefficient should be used in other plants. However, different flow conditions (temperature, pressure, quality factor) may dictate adjustments of these parameters.	Acceptable – the speed of sound is based on the thermodynamic properties of steam in the RPV
Other	Model Benchmarking	PBLE is benchmarked against previously instrumented dryer data
Other	Determination of Biases and Uncertainty	Biases and Uncertainty have been calculated

Note that other sections of Reference 1 refer to structural analysis of the steam dryer or preoperational/startup testing that is outside of the scope of this Licensing Topical Report.

4.3 Range of Application

The PBLE method described in this report is capable of determining the vibratory forcing function for the entire operating range of the ESBWR steam dryer.

4.4 Plant-Specific Application Methodology

4.4.1 [[ ]] Model Inputs

The vessel [[

]]

Acoustic Finite Element Model Mesh

A FE model of the [[

]]

[[ ]]

Figure 18. [[ ]]

[[

]]

4.4.2 Plant Input Measurements

Sensor Type and Location

For the PBLE [[

]]

Error in Measured Dryer Pressures

This error, [[

]]

4.4.3 Plant-Specific Load Definition

The following steps are involved in the calculation of dryer loads with the PBLE: [[

]]

4.4.4 Application Uncertainties and Biases

This section describes the processes for how to calculate the PBLE uncertainties for a plant-specific application.

The methodology presented here provides an uncertainty due to errors in the PBLE inputs: [[

]]

4.4.4.1 Method Presentation

This section describes constituting elements of the uncertainty analysis: the varying input parameters, the statistical methods in use, the nominal case and how deviations from the nominal case are calculated.

Parameters in the Uncertainty Analysis

The code parameters and variables that have an influence in the load definition are listed in Table 5. All influence [[ ]]

Table 5 Parameters in the [[ ]]

Phenomena	**Parameter**
[[	
	]]

Analysis Techniques

The techniques used in the evaluation of the uncertainty are briefly introduced in the following paragraphs.

Design of Experiments

A Design of Experiment (DOE) is a structured, organized method for determining the relationship between parameters affecting a process and the output of that process. Forced changes are made methodically to the input parameters as directed by mathematically systematic tables and the impact on the results is assessed. It is suitable for the present study since it allows maximizing information with a limited number of well-chosen parameter variations. The effect of input variables can be judged when acting alone, or in combination with others.

For each input parameter, a number of possible values are defined, representing the known variation range for each variable. [[

]]

Monte Carlo Analysis

The Monte Carlo method is a way to statistically evaluate a system using random samples. The larger the number of random samples is, the more accurate the results. From the mathematical point of view it consists of choosing a large number of parameter values at random from within a variation interval. It is useful to assess uncertainty when the ranges of the input parameters can not be given in a deterministic way (upper and lower bounds), but their probability density functions are known.

Deviations from Nominal Case

The nominal case corresponds to the PBLE results with all parameters at their best known values. These results are obtained by following the guidelines outlined in Section 4.4. [[

]]

4.4.4.2 Step 1 – Sensitivity of [[ ]]

Aside from parameters related to numerical accuracy, a range of values is known for each parameter in Table 5. [[

]]

Based on the results of these DOEs, [[

]]

[[ ]]

Figure 19. [[ ]]

Numerical Accuracy

The uncertainty due to [[

]]

4.4.4.3 Step 2 - Uncertainty in [[ ]]

Once [[ ]] that take into account the influence of the sensitive parameters in Table 5 have been pre-computed, the overall uncertainty in the PBLE loads can be evaluated.

[[

]]

4.4.4.4 Combination of Uncertainties and Biases

Individual uncertainties (due to different parameters or groups of parameters) are combined into a single one by taking the square root of the sum of the squares (SRSS):

$$(22)\quad U = \sqrt{\sum u_i^2} \quad \text{where:}$$

U = Total uncertainty

u_i = Individual uncertainties

If the parameters or groups of parameters are not independent from each other, the combined uncertainty is conservative.

A benchmark against measured dryer pressures would produce a bias and an uncertainty in each frequency band. Then the total bias of the PBLE loads is the benchmark bias and the total uncertainty is a SRSS in which the benchmark uncertainty is a term of the sum.

4.5 Demonstration Analysis

This section details how uncertainties are combined in the example of Section 3.3.2: QC2 at EPU condition, [[ ]] The QC2 at OLTP had a different set of acoustic frequencies and benchmark results, but the bias and uncertainties would be calculated and assessed in the same manner.

The deviation from measured data (bias and uncertainty) is covered in the benchmark section (Section 3.3.2). The bias [Equation (17)] indicates any [[

]]

For QC2 at EPU, the biases and uncertainties from the comparison between nominal projections and measured pressures are in Figure 17. The uncertainties due to the model parameters is calculated in detail in Appendix C.

For the PBLE from in-vessel pressures, the contributors are: [[

]]

The consolidated results are shown in Table 6 and Figure 20. In Figure 20 the predicted summed PSDs are also corrected with the biases from the benchmark against test data.

[[ ]]

Figure 20. PBLE [[ ]] - Range of Predictions Versus Measurements

Table 6 Total Bias and Uncertainty for PBLE from [[ ]] for QC2 at EPU

Frequency Band (Hz)	8 -10	13 - 16	22 - 28	28 - 34	38 - 46	48 - 58	132 - 145	146 - 153	154 - 158	159 - 168	146 - 158
BIAS (%)											
[[ ]]	**-8.36**	**-6.43**	**8.49**	**6.28**	**5.47**	**-12.04**	**-14.20**	**20.99**	**-4.70**	**-4.70**	**9.60**
UNCERTAINTY (%)											
[[	8.74	4.79	2.98	2.06	1.44	2.67	2.89	0.76	0.97	3.00	1.08
	0.86	0.82	0.95	0.66	0.76	6.07	3.85	10.64	2.18	4.62	6.30
	2.89	3.57	3.99	3.83	3.11	2.96	3.07	4.03	3.69	2.69	3.87
	0.38	0.49	0.36	0.24	0.62	0.66	2.69	2.46	1.31	1.88	1.99
]]	0.91	1.12	1.24	0.95	0.64	0.76	3.08	4.63	1.56	3.41	3.40
Total uncertainty (SRSS)	**9.30**	**6.15**	**5.23**	**4.51**	**3.62**	**7.33**	**7.02**	**12.55**	**4.84**	**7.26**	**8.45**

5.0 CONCLUSIONS

The Plant Based Load Evaluation methodology [[ ]] is available to predict dryer pressure loads and their associated uncertainty.

A built-in [[

]]

The PBLE technique is validated by the Quad Cities 2 application case. From comparison between measurements and projections, the PBLE predicts good frequency content and spatial distribution. The SRV valve resonances are well captured. The PBLE predictions are highly accurate: the low frequency content below [[

]] These good results validate the main assumption that [[ ]] to reproduce measured dryer pressures, including low frequencies.

The PBLE addresses a wide range of load cases:

- MSL valve resonance (SRV/branch line) or broadband excitations (venturi)
- Sources in the vicinity of nozzles
- Hydrodynamic loading (pseudo-pressures)

The effects from the last two types of sources can be advantageously modeled by [[ ]]; for this reason the PBLE from [[ ]] is adequate to predict fluctuating dryer loads at any BWR plant.

6.0 REFERENCES

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[12] U.S. Nuclear Regulatory Commission, NUREG-0800, Revision 3, March 2007, Section 3.9.2, "Dynamic Testing and Analysis of Systems, Structures and Components."

[13] U.S. Nuclear Regulatory Commission, NUREG-0800, Revision 3, March 2007, Section 3.9.5, "Reactor Pressure Vessel Internals."

APPENDIX A QC2 OLTP BENCHMARKS PSDS

[[ ]]

Measured –Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
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Measured - Red
[[ ]] - Green
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Measured - Red
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[[ ]] - Blue

APPENDIX B QC2 EPU BENCHMARK PSDS

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
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[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

[[ ]]

Measured - Red
[[ ]] - Green
[[ ]] - Blue

APPENDIX C QC2 EPU UNCERTAINTY ASSESSMENT

C.1. VARIATIONS IN PBLE INPUT PARAMETERS

Table 7 Nominal, Upper and Lower Bound Parameter Values for QC2

	Units	Nominal	Lower	Upper
[[				
				]]

Table 7 gives the nominal values and the upper and lower limits for all the input parameters. The [[ ]] is described in Section 2.2.2. In addition to the content of Table 7, [[ ]]

C.2. STEP 1 – SENSITIVITY OF FRFS

The goal of this step is to determine which variables in the vessel have an influence in [[

]]

Mesh Independent Parameters

Figure 21 shows results, for high and low frequency respectively, for the DOE [[ ]]

The curves for all experiments lay on top of each other. No variability is observed due to these parameters in their variation range.

Figure 22 shows results [[ ]] For this group of variables some differences are observed. By observing the [[

]]

[[ ]]

Figure 21. DOE on [[ ]]

[[ ]]

Figure 22. DOE on [[ ]]
Black Thick Line is the Nominal Experiment

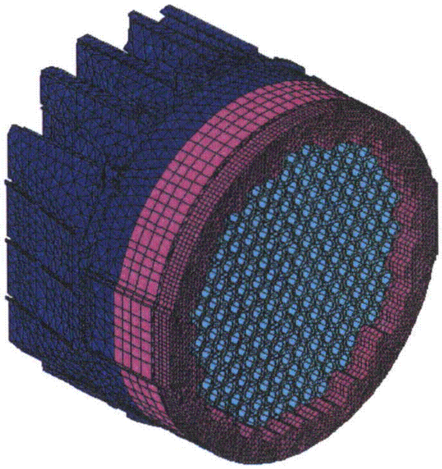

Figure 23. FEM Mesh Upstream the Dryer Showing the Regions With [[
]]

[[

]]

Table 8 Changes in [[ ]]

	[[	
Mesh 1		
Mesh 2		
Mesh 3		]]

Table 9 Acoustic Modes (Hz) of the Nominal and Modified Meshes

Modes	Nominal	Mesh 1	Mesh 2	Mesh 3
1	[[			
2				
3				
4				
5				
6				
7				
8				
9				
10				]]

[[ ]]

Figure 24. FRFs for Different FE Meshes With [[ ]]

[[ ]]

In view of [[

]]

Table 10 [[ ]]

	[[	
		]]

[[

]] In any case, the curves reproduce each other reasonably well.

[[ ]]

Figure 25. FRFs With Finer FE Mesh

Figure 26 [[

]]

[[ ]]

Figure 26. [[ ]]

C.3. STEP 2 – UNCERTAINTY IN DRYER LOADS

From the previous section, it is clear that [[

]]

[[ ]]

Figure 27. [[ ]]

Table 11 [[

]]

[[						
						]]

Table 12 [[

]]

[[					
					]]

Uncertainty due to Errors in the Measurement Loop

It has been shown in a previous report [11] that this measurement loop, [[

]] The results are shown in Figure 28 and quantified in Table 13 and Table 14.

Table 13 PBLE predictions – Measurement Loop Deviations from Nominal at Low Frequencies

Frequency band (Hz)	8 – 10	13 – 16	22 – 28	28 – 34	38 – 46	48 – 58
Upper deviation (%)	[[					
Lower deviation (%)						]]

Table 14 PBLE predictions – Measurement Loop Deviations from Nominal at High Frequencies

Frequency band (Hz)	132 – 145	146 – 153	154 – 158	159 – 168	146 – 158
Upper deviation (%)	[[				
Lower deviation (%)					]]

[[ ]]

Figure 28. PBLE Predictions – Uncertainty Due to the Measurement Loop

Uncertainty due to [[ ]]

The uncertainty [[

]]

Table 15 [[

]]

[[						
Deviation (%)						
Deviation (%)						]]

Table 16 [[

]]

[[					
Deviation (%)					
Deviation (%)					]]

C.4. CONSOLIDATED UNCERTAINTY

The results are shown in Figure 29, Table 17 and Table 18. The largest contribution to uncertainty [[

]]

The overall uncertainty remains below 10%, except for the 146 – 153 Hz bands, where it peaks at a value of 12.55%.

Table 17 Consolidated Uncertainty – [[ ]]

Frequency Bands (Hz)	8 -10	13 - 16	22 - 28	28 - 34	38 - 46	48 - 58
[[						
						]]

Table 18 Consolidated Uncertainty – [[ ]]

Frequency Bands (Hz)	132 - 145	146 - 153	154 - 158	159 - 168	146 - 158
[[					
					]]

In Figure 29, the PBLE uncertainties are quite small but some bias compared to the measured PSDs remains; this is reconciled by the benchmark against measured pressures in Section 3.3.2.

[[ ]]

Figure 29. PBLE from [[ ]]

MFN 09-515

Enclosure 3

Affidavit

GE-Hitachi Nuclear Energy Americas LLC

AFFIDAVIT

I, David H. Hinds, state as follows:

(1) I am the Manager, New Units Engineering, GE Hitachi Nuclear Energy ("GEH"), have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of GEH letter MFN 09-515, Mr. Richard E. Kingston to U.S. Nuclear Regulatory Commission, entitled *Transmittal of GEH Licensing Topical Report (LTR) "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology," NEDC-33408P, Revision 1, July 2009,* dated August 3, 2009. The GEH proprietary information in Enclosure 1, which is entitled *GEH Licensing Topical Report (LTR) "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology," NEDC-33408P, Revision 1 – Proprietary Version* 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. A non-proprietary version of this information is provided in Enclosure 2, *GEH Licensing Topical Report (LTR) "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology," NEDO-33408, Revision 1 – Public Version.*

(3) In making this application for withholding of proprietary information of which it is the owner, 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 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, 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 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 identifies detailed GEH ESBWR design information. GEH utilized prior design information and experience from its fleet with significant resource allocation in developing the system over several years at a substantial cost.

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 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 August, 2009.

David H. Hinds
GE-Hitachi Nuclear Energy Americas LLC