Enclosure 6

MFN 13-091

GE Hitachi Nuclear Energy, "ESBWR Steam Dryer Acoustic Load Definition," NEDO-33312, Rev. 5, Class I (Non-Proprietary), December 2013

Public Version

This is a non-proprietary version of Enclosure 2, from which the proprietary information has been removed. Portions of the document that have been removed are identified by white space within double brackets, as shown here [[ ]].

HITACHI

GE Hitachi Nuclear Energy

NEDO-33312
Revision 5
DRF Section 0000-0077-3671 R11
December 2013

Non-Proprietary Information-Class I (Public)

Engineering Report

ESBWR STEAM DRYER ACOUSTIC LOAD DEFINITION

INFORMATION NOTICE

This is a non-proprietary version of the document NEDE-33312P, Revision 5, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING THE CONTENTS OF THIS REPORT

Please Read Carefully

REVISION SUMMARY

This table includes revisions to NEDO-33312 from Revision 4 to Revision 5.

Location	Comment
Title and Cover Page	Updated the revision number and date for the new report version. See response to RAI 3.9-299, Part b.
Abstract	At beginning of second paragraph, changed "Revision 4 of this report describes…" to "This report describes…". Added "(Reference 1)" after "Regulatory Guide 1.20 Revision 3", and "(Reference 2)" after "Engineering Report NEDE-33313P".
S1.0	In first paragraph, item (2), changed "load" to "loads". Deleted details regarding approach used for the ESBWR steam dryer structural evaluation, instead pointing to Engineering Report NEDE-33313P (Reference 2) for that information, and modified proprietary marking accordingly.
S2.2	In first paragraph, last sentence, changed "evaluate" to "evaluates".
S6.0	Revised the revision number and date of Reference 2 to refer to the latest revision of NEDE-33313P. Revised the revision number and date of Reference 3 to refer to the latest revision of NEDE-33408P.

Table of Contents

List of Tables

List of Figures

ACRONYMS AND ABBREVIATIONS

Term	Definition
ABWR	Advanced Boiling Water Reactor
BWR	Boiling Water Reactor
CFD	Computation Fluid Dynamics
EPU	Extended Power Uprate
ESBWR	Economic Simplified Boiling Water Reactor
FRF	Frequency Response Functions
GEH	GE Hitachi Nuclear Energy
FE	Finite Element
FEM	Finite Element Model
FIV	Flow Induced Vibration
ID	Inside Diameter
MSIV	Main Steam Isolation Valve
MSL	Main Steam Line
OLTP	Original Licensed Thermal Power
PBLE01	Plant Based Load Evaluation
PSD	Power Spectral Density
RMS	Root Mean Square
RPV	Reactor Pressure Vessel
SST	Shear Stress Transport

ABSTRACT

This document describes the GE Hitachi Nuclear Energy (GEH) approach used to develop the Economic Simplified Boiling Water Reactor (ESBWR) flow induced vibration (FIV) load definition for the ESBWR steam dryer. There has been much development in FIV load modeling in the last several years, including techniques developed using measurements taken from several operating plants. Events in the industry including technical developments and regulatory interactions have dictated that GEH further develop the ESBWR Steam Dryer Load Definition approach. The current GEH approach to load definition is defined as the Plant Based Load Evaluation (PBLE01) method, which is described in Reference 3.

This report describes the ESBWR Steam Dryer Load Definitions with the PBLE01 method. The GEH approach to the ESBWR FIV load definition focuses on utilizing an ABWR-based steam dryer design, allowing the use of instrumented ABWR in-plant steam dryer test data to form the basis for the ESBWR load definition. This basic load definition will then be further improved through comparison with testing and operating experience gained from GEH Extended Power Uprates (EPUs) conducted on several operating plants.

The development of the FIV loads as described here are in accordance with Regulatory Guide 1.20 Revision 3 (Reference 1). The FIV loads will be used in combination with other design loads in qualifying the steam dryer as described in Engineering Report NEDE-33313P (Reference 2).

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 (Reference 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 loads 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 approach used for the ESBWR steam dryer structural evaluation is described in Section 1.0 of Engineering Report NEDE-33313P (Reference 2).

[[

]]

2.0 ESBWR DRYER CONFIGURATION

2.1 Dryer and RPV Geometry

A key aspect in the development of the ESBWR FIV load definition is to incorporate the ABWR dryer geometry. By minimizing the geometrical differences between the ABWR and the ESBWR steam dryers, this approach will build on the successful operating experience of the ABWR steam dryer and will allow the ABWR steam dryer measurement data to be used in developing the FIV load definition for the ESBWR. The ESBWR and ABWR have the same RPV inside diameter (ID) and main steam line (MSL) outlet nozzle configuration. Both plants have the venturi-flow restrictor as a component of the MSL nozzle. Figure 2.1-1 provides a comparison of the ABWR and ESBWR vessel in the steam dome region.

The six bank dryer used in the ESBWR will have similar vane height, skirt length, and water submergence as the ABWR steam dryer. The ESBWR steam flow rate will be approximately 15% higher than the ABWR. There is less neck down in the vessel head flange region of the ESBWR than in the ABWR. This will provide additional clearance allowing a larger dryer diameter and longer vane banks (more vanes) to be used in the ESBWR dryer steam.

[[

]] There is less vessel neck-down at the vessel flange; therefore, the plenum area between the dryer and vessel above the MSL nozzles is larger.

The vessel head for ABWR is hemispherical; the ESBWR uses a torispherical head, [[

]] The effect of these differences on the acoustic response will be evaluated as discussed in Sections 3.1 and 3.2 of this report.

The ABWR steam dryer, shown in Figure 2.1-2, was instrumented as part of the ABWR startup and power ascension test program. This instrumentation provides test data that can be used as a benchmark for the ESBWR FIV design loads. There have been no identified FIV problems with the in-service ABWR steam dryers. As shown in Figure 4.1-1, the ABWR steam dryer test data indicates that the amplitudes of acoustic loads in the ABWR dome are low.

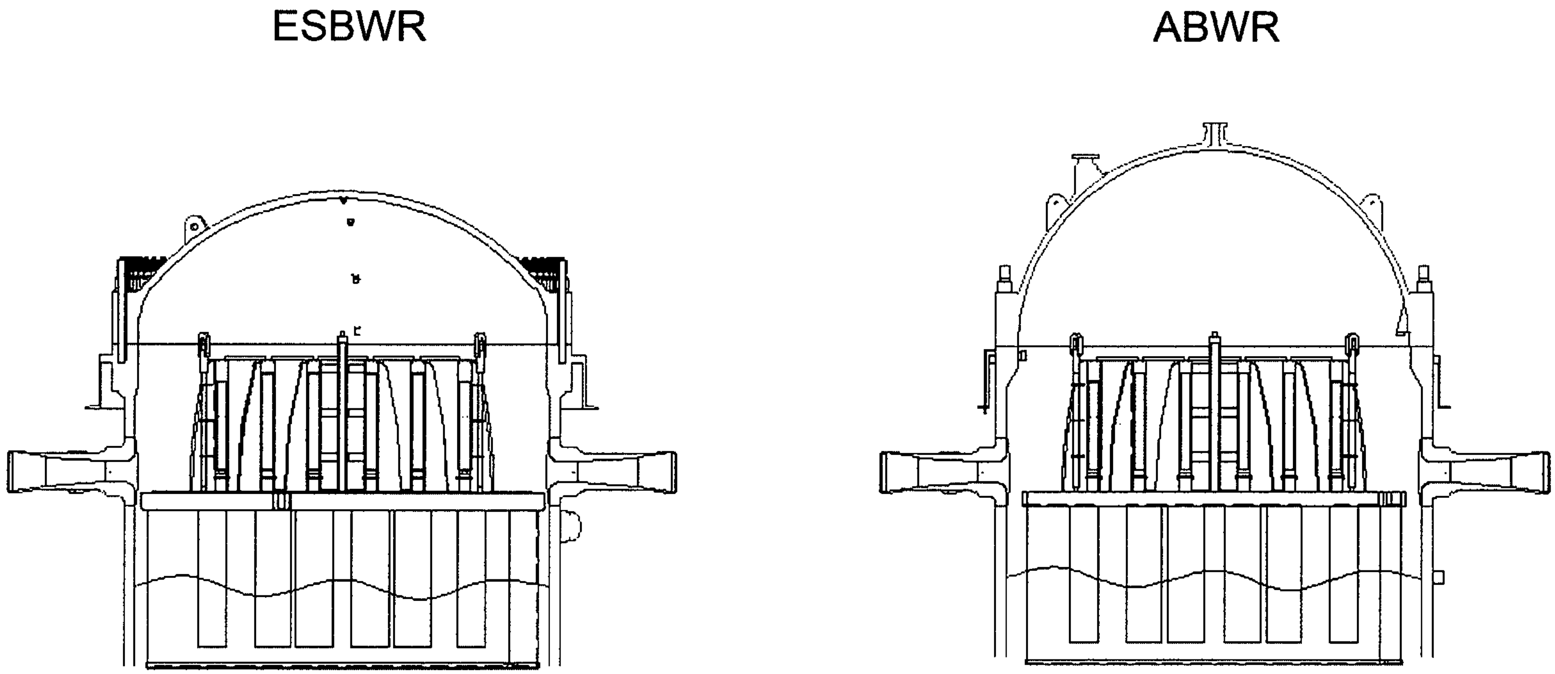

Figure 2.1-1. Comparison of Planned ESBWR and Typical ABWR Vessel Steam Regions

[[

]]

Figure 2.1-2. Depiction of ABWR Steam Dryer with Test Instrumentation

P: Pressure Transmitter

S: Strain Gage

A: Accelerometer

2.2 Comparative CFD Analysis

A comparison of the ABWR and ESBWR geometry and flow changes to the flow patterns and hydrodynamic loads on the steam dryer is further evaluated with CFD. The steam dome, outlet nozzle and a portion of the downstream steam line of the ABWR and ESBWR is modeled with CFD. The CFD study [[

]]

3.0 ACOUSTIC FINITE ELEMENT MODELING OF THE RPV AND STEAM-LINES

3.1 RPV Steam Dome Acoustic Finite Element Model

[[

]]

3.2 Coupled RPV Steam Dome and Main steam Lines Acoustic Finite Element Model

[[

]]

4.0 FIV LOAD DEFINITION BASED ON DATA FROM PLANT INSTRUMENTATION

4.1 FIV Loads Developed from Data from Multiple Plants

[[

]]

Figure 4.1-1 includes comparison of instrumented steam dryer data for [[

]]

Table 4.1-1 provides a comparison of geometry and flow parameters for the ESBWR, the ABWR at full power and the BWRs at extended power uprate conditions.

Figure 4.1-1 includes a comparison of PBLE01 load projections based on test data from both [[

]]

A comparison of the root mean square (RMS) values of the selected plant data sets and the ABWR test data shown in Figure 4.1-1 is included in Table 4.1-2. The design loads RMS values are approximately 50% higher than the measured ABWR data factored to ESBWR steam flow velocity conditions.

The ESBWR steam dryer loads are generated by [[

]]

The structural assessment for each set includes a +/-10% frequency variation to provide a range of applied load frequencies. [[

]]

A frequency dependent bias and uncertainty evaluation is included in the structural evaluation for areas of the steam dryer with the highest alternating stress.

[[

]] This methodology identifies the acoustic load frequencies and associated steam dryer structural response modes that are most affected by FIV loads. [[

]]

Table 4.1-1 Comparison of Geometry and Flow Parameters

[[						
						]]

Table 4.1-2 RMS Comparison of Loads and Test Data

	[[			
				]]

[[

]]

Figure 4.1-1. PSD Comparison of Loads and Test Data

5.0 FIV LOAD MITIGATION

5.1 FIV Load Mitigation Through Design

As described in Section 3, [[

]]

6.0 REFERENCES

[1] Regulatory Guide 1.20, "Comprehensive Vibration Assessment Program For Reactor Internals During Preoperational And Initial Startup Testing," Revision 3, March 2007.

[2] GE Hitachi Nuclear Energy, "Steam Dryer - Structural Evaluation," NEDE-33313P, Revision 5, Class III (Proprietary), December 2013, and NEDO-33313, Revision 5, Class I (Non-Proprietary), December 2013.

[3] GE Hitachi Nuclear Energy, "ESBWR Steam Dryer – Plant Based Load Evaluation Methodology, PBLE01 Model Description," NEDE-33408P, Revision 5, Class III (Proprietary), December 2013, and NEDO-33408, Revision 5, Class I (Non-Proprietary), December 2013.