GE Energy

James C. Kinsey
Project Manager, ESBWR Licensing

PO Box 780 M/C J-70
Wilmington, NC 28402-0780
USA

T 910 675 5057
F 910 362 5057
jim.kinsey@ge.com

MFN 07-268

Docket No. 52-010

May 16, 2007

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **Response to Portion of NRC Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application – DCD Section 3.9 – RAI Number 3.9-134**

Enclosure 1 contains GE's response to the subject NRC RAI transmitted via the Reference 1 letter.

If you have any questions or require additional information regarding the information provided here, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

D068

Reference:

1. MFN 06-378, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application,* October 10, 2006

Enclosure:

1. MFN 07-268 – Response to Portion of NRC Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application – DCD Section 3.9 – RAI Number 3.9-134

cc:	AE Cubbage	USNRC (with enclosures)
	DH Hinds	GE (with enclosures)
	RE Brown	GE (w/o enclosures)
	eDRF	0000-0067-7515

Enclosure 1

MFN 07-268

Response to Portion of NRC Request for

Additional Information Letter No. 67

Related to ESBWR Design Certification Application

DCD Section 3.9 – RAI Number 3.9-134

NRC RAI 3.9-134

GE states that most recent BWR steam dryer fatigue failures have been caused by 'strong narrow-band pressure loads' at frequencies between 120 and 200 Hz that emanate from acoustic resonances in the safety relief valve (SRV) standpipes (DCD Tier 2, Section 3L.4.4, page 3L-8),and that 'the ESBWR SRV standpipe design is intended to reduce or eliminate acoustic resonances in these branch lines'.

a. GE is requested to describe the design of the ESBWR SRV standpipes summarizing (1) dimensions of the SRVs, standpipes, and the MSLs; (2) expected steam flow speeds near the SRV standpipes; (3) plant power levels at which acoustic resonances in the standpipes might be strongly excited, along with the frequencies of the resonances and their expected amplitudes; and (4) the proximity of various SRVs to each other on individual MSLs.

b. GE plans to limit the data acquisition, signal processing, and data interpretation of all FIV testing during prototype ESBWR power ascension to frequencies below 200 Hz (and, in some cases, below 100 Hz), as shown in DCD Tier 2, Tables 3L-5 and 3L-6, and described in DCD Tier 2, Section 3L.5.4. GE is requested to justify this frequency limit based on submission of complete SRV standpipe ESBWR design criteria in part (a).

c. In addition to the instrumentation for the steam dryer in the prototype ESBWR for FIV testing, GE is requested to submit a list of instrumentation planned for the SRVs and MSLs, and justification where such instrumentation will not be installed.

GE Response

a.) The ESBWR SRV standpipe design is currently under evaluation. The entrance to the standpipe is being designed to minimize the resonant feedback effect on the shear layer instability, thus minimizing the amplitude of potential resonances in the standpipe. Scale model testing will be performed on the individual MSLs in order to determine the optimum locations that minimize valve-to-valve interaction.

b.) The frequency ranges shown in DCD Tier 2, Tables 3L-5 and 3L-6, and described in DCD Tier 2, Section 3L.5.4 are approximate. The frequency ranges being monitored in the FIV test program will be adjusted to bound the range of frequencies determined in the FIV evaluations for the final ESBWR design.

c.) For main steam line acoustic monitoring, at least 2 locations will be monitored on each MSL in the containment. The instruments at each location will include either a minimum of 4 strain gages orientated in the hoop direction or 1 piezoelectric pressure transmitter mounted flush with the inside wall of the pipe. The data sampling rate will be high enough to resolve the frequencies associated with potential acoustic resonances in the SRV standpipes. The amplification and sensitivity and max sample rate of the data acquisition equipment will be sufficient to define temporal acoustic steam line data.

DCD Impact

DCD Tier #2, Subsections 3L.4.4 and 3L.5.4, Tables 3L-5 and 3L-6 were revised in revision 3 as noted in the attached markup.

avoided by careful control of the solution heat treatment, sensitization testing and testing for intergranular attack (IGA).

3L.4.3 Load Combinations

Design loads for the steam dryer will be based on evaluation of the ASME load combinations provided in Table 3.9-2 except that the load definitions that pertain to the steam dryer are modified as shown in Table 3L-2. These load combinations consist of dryer deadweight loads, static and fluctuating differential pressure loads (including turbulent and acoustic sources), seismic, thermal, and transient acoustic and fluid impact loads.

3L.4.4 Fluid Loads on the Dryer

During normal operation, the dryer experiences a static differential pressure loading across the dryer plates resulting from the pressure drop of the steam flow across the vane banks. The dryer also experiences fluctuating pressure loads resulting from turbulent flow across the dryer and acoustic sources in the vessel and main steamlines. During transient and accident events, the dryer may also experience acoustic and flow impact loads that result from system actions (e.g., turbine stop valve closure) or from the system response (e.g., the two-phase level swell following a main steamline break).

Of particular interest are the fluctuating pressure loads that act on the dryer during normal operation that has led to fatigue damage in previous dryer designs. Scale model testing has identified the likely sources of fluctuating pressure loading acting on the steam dryer. The results of this testing showed that the fluctuating pressure load frequency spectrum can be divided into four regions based on the postulated source of the loading:

- **0-10 Hz:** The pressure loads in this frequency range are dominated by the fundamental main steamline piping acoustics. The source of these pressure loads is believed to be turbulence in the main steamline or vortex shedding in steam dome.
- **10-30 Hz:** The source of the pressure loads in this frequency range is postulated to be a stationary vortex on the outer hood of the steam dryer adjacent to the vessel outlet nozzles. The frequency characteristics of this pressure loading may be governed by harmonics of the main steamline acoustics.
- **>30 Hz:** The lowest steam plenum acoustic modes are located in this frequency range. The dominant excitation is due to broadband turbulent sources located in main steamlines but the acoustic modes may also be excited by sources in the vessel. The plenum acoustic modes have a very high amplification effect on pressure oscillations in this frequency range. The lower frequency vessel acoustic modes exhibit the most significant response to the turbulent excitation present in the system. Higher frequency vessel acoustics exist but are not significantly excited except as discussed below.
- **120-200 Hz:** Strong narrow band pressure loads in this frequency range are caused by acoustic resonances in safety and relief valve branch lines attached to the main steamlines. Higher frequency steam plenum acoustic modes can be excited if the vessel is acoustically coupled to the branch line. The ESBWR SRV standpipe design is intended to reduce or eliminate acoustic resonances in these branch lines. It should be noted that the 120-200 Hz frequency range is approximate and is dependent on the SRV

RAI 3.9-134

standpipe design. The frequency range monitored in the FIV test program will be adjusted to bound the range of frequencies determined for the final design. RAI 3.9-134

A detailed description of the acoustic load definition process for the ESBWR steam dryer is provided in Reference 3L-5. The steam dryer acoustic load definition process consists of three primary elements:

- Scale model testing (physical testing using an ESBWR scale model to acquire load definition data, pressure and frequency, monitored by approximately 60 transducers),
- Acoustic finite element modeling of the reactor steam dome region to determine the natural frequencies and mode shapes of the steam volume, and
- A load interpolation algorithm to refine the measured fluctuating load into a fine mesh consistent with the structural finite element model nodalization in order to perform an accurate stress analysis of the dryer.

Flow induced turbulent and acoustic loads for the design of the ESBWR steam dryer will be determined from scale model testing of the dryer design and resultant acoustic modeling performed in the GE scale model testing facility located at the Vallecitos Nuclear Center in Sunol, California. The scale model test apparatus models the outside surface of the steam dryer above the vessel water level, the vessel steam dome region, and the main steamline piping to the turbine inlet, including major branch lines (e.g., SRV standpipes, turbine bypass piping). The testing is performed in ambient air conditions. Because the fluctuating pressure loads are primarily acoustic in nature, the test results are scaled to reactor conditions while preserving an equivalent Mach number between the model and the plant. GE has recently successfully completed a power ascension test program with an instrumented replacement BWR 3 steam dryer that is the prototype for the ESBWR steam dryer. The scale model test has been benchmarked against the plant data acquired from this instrumented dryer and confirms the capability of the GE scale model test methodology to predict the steam dryer acoustic load definitions. RAI 3.9-134

The acoustic finite element modeling models the steam dryer and reactor steam dome cavity. This model is used to predict the acoustic mode shapes of the cavity and provides the framework for the load interpolation algorithm.

The load interpolation algorithm is used to provide a fine mesh load definition for input to the dynamic structural analysis. The algorithm uses the acoustic normal modes of the RPV steam plenum as a basis to describe the domain of interest. The algorithm uses the test measurements taken from the approximately 60 transducer locations on the scale model test and the acoustic finite element model to develop a fine-mesh array of pressure time histories that are consistent with the structural finite element model nodalization.

3L.4.5 Structural Evaluation

A finite element analysis (FEA) will be performed to confirm that the ESBWR steam dryer is structurally acceptable for operation. The FEA will use the scale model test loads as input. The finite element analysis will be performed using a whole dryer analysis model of the ESBWR steam dryer to determine the most highly stressed locations. The FEA consists of time history dynamic analyses for the load combinations identified in Table 3.9-2. If required, locations of capability of the internals, steady-state test conditions are the most important conditions to evaluate.

Total volumetric core flow rate is also an important parameter that affects the vibration magnitude of the internals. Vibration amplitude generally increases as the volumetric flow rate increases.

3L.5.4 Data Reduction Methods

Basically, two types of data reduction are performed: (1) time history analyses and (2) spectrum analyses. In either data reduction method, the measured peak-to-peak (p-p) value of each sensor signal is compared to the allowable p-p value. Even though both time history and spectrum analyses are performed for each selected sensor and test condition, the results from only one data reduction method are used for comparison to the allowable values. The selection of the method is dependent on the analysis method used for data evaluation. The different methods of data evaluation are described in detail in Section 3L.5.5. Briefly, Method I is used for components that have many closely spaced natural vibration modes and utilizes the strain energy weighting method applied to all modes over the frequency range of interest. This method has previously been applied to the In-core Monitor (ICM) housings, shroud, top guide, and steam dryer skirt and support ring. Method II is similar to Method I, except that it is applied to two frequency bands, 0-100 Hz and 100-200 Hz. This method has previously been applied to the steam dryer drain channels and hood. Method III is used for components that have relatively few, distinct dominant natural modes that are matched to the analytical modes. This method has previously been applied to the in-core guide tubes. Table 3L-5 describes the method of data reduction that is applicable to each component. It should be noted that the 200 Hz frequency range is approximate and is dependent on the SRV standpipe design. The frequency range monitored and evaluated in the FIV test program will be adjusted to bound the range of frequencies determined for the final SRV standpipe design. RAI 3.9-134

3L.5.4.1 Time History Analysis

The time history method uses the analyzer's time capture mode of operation. The time capture is performed for a period of several minutes for all the selected sensors and test conditions. The frequency bandwidth for the time capture is chosen to accommodate 0-200 Hz as a minimum for most channels.

For comparison to the allowable vibration amplitude, the measured peak-to-peak (p-p) value over specified bandwidths needs to be obtained for sensors in specific components. The bandwidths used for p-p measurements for various components are shown in Table 3L-5. There are four bandwidths for time history p-p measurement: 0-200 Hz, 0-100 Hz, 100-200 Hz and 0-1600 Hz. The 0-1600 Hz is used only for the accelerometer for the purpose of detecting impacts. The other three bandwidths are used for normal vibrations.

For the 0-200 Hz bandwidth, the maximum p-p values over several minutes of data for selected sensors and test conditions are obtained directly from the time capture. Specification of the bandwidth for time capture (0-200 Hz) automatically results in a low-pass filtered signal.

In order to obtain the maximum p-p in the 0-100 Hz range, the histogram operation is employed on the time capture traces. When the bandwidth (0-100 Hz) is specified in the histogram operation, the signal is automatically low-pass filtered in the specified frequency range. The

Table 3L-5

Applicable Data Reduction Method for Comparison to Criteria

Component	Sensor Type	Applicable Data Reduction Method		Frequency Bandwidth (Hz)*
Shroud	Strain Gages	I	Time History	0-100
Steam Dryer Skirt	Strain Gages	I	Time History	0-100
Steam Dryer Drain Channels	Strain Gauges	II	Time History	0-100, 100-200
Steam Dryer Hoods	Strain Gages	II	Time History	0-100, 100-200
Steam Dryer Support Ring	Accelerometer	Impact	Time History	0-1600 0-80, 80-200
Top Guide	Displacement	I	Time History	0-100
Vessel Annulus	Pressure sensors	I	Time History	0-200
Standby Liquid Control Lines	Strain Gages	I	Time History	0-200

* It should be noted that the 200 Hz frequency range is approximate and is dependent on the SRV standpipe design. The frequency range monitored and evaluated in the FIV test program will be adjusted to bound the range of frequencies determined for the final SRV standpipe design.

RAI 3.9-134

Table 3L-6

Parameters Used in Spectrum Generation

Parameter	Value
Bandwidth	0-200 Hz*
Time length	3 minutes
No. of Fourier Lines	400
Resolution	0.5 Hz
Window	Flat Top
No. of averages	90
Overlap	0%
Noise reduction	None
Average Type	Peak-hold
P-P Value	= RMS x 6

* It should be noted that the 200 Hz frequency range is approximate and is dependent on the SRV standpipe design. The frequency range monitored and evaluated in the FIV test program will be adjusted to bound the range of frequencies determined for the final SRV standpipe design.

RAI 3.9-134

Table 3L-7

Data Evaluation Methods to be Used for Each Component

Internal Component	Data Evaluation Method Used
Shroud and Chimney	I
Steam Dryer	I & II
Standby Liquid Control Line	I