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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application – Main Steam, Feedwater and Other Class 1 Piping – RAI Numbers 3.9-20, 3.9-65, 3.9-68, 3.9-70**

Enclosure 1 contains GE's response to the subject NRC RAIs 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 07-234 – Response to Portion of NRC Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application – Main Steam, Feedwater and Other Class 1 Piping – RAI Numbers 3.9-20, 3.9-65, 3.9-68, 3.9-70

| | | |
|---|---|---|
| cc: | AE Cubbage | USNRC (with enclosures) |
| | DH Hinds | GE (with enclosures) |
| | RE Brown | GE (w/o enclosures) |
| | eDRF | 0000-0066-3036 |

**Enclosure 1**

**MFN 07-234**

**Response to Portion of NRC Request for**

**Additional Information Letter No. 67**

**Related to ESBWR Design Certification Application**

**Main Steam, Feedwater and Other Class 1 Piping**

**RAI Numbers 3.9-20, 3.9-65, 3.9-68, 3.9-70**

## NRC RAI 3.9-20

*The discussion under 'Reconciliation and Corrective Actions' in DCD Tier 2,Section 3.9.2.1.1, does not clearly explain how remote measurements during testing would ensure compliance with the acceptance criteria. Discuss in greater detail to explain how remote measurements are regularly checked during tests to verify compliance with acceptance criteria. The discussion should cover the vibration measurement and analysis methodology including the approximate number of locations monitored, the specific systems covered by this monitoring, basis for selection of systems and locations as well as the instrumentation/analyzers used for such monitoring. Alternately, provide a reference document which describes the vibration/condition monitoring program.*

## GE Response

Refer to Attachment B "ESBWR Startup Acceptance Criteria For Piping" which explains how remote measurements during testing ensure compliance with the acceptance criteria, how remote measurements are regularly checked during tests to verify compliance with acceptance criteria, the vibration measurement and analysis methodology including the approximate number of locations monitored, the specific systems covered by this monitoring, the basis for selection of systems and locations as well as the instrumentation/analyzers used for such monitoring.

## DCD Impact

No DCD changes will be made in response to this RAI.

**NRC RAI 3.9-65**

*The discussion provided in DCD Tier 2, Section 3.9.2.4 does not specifically state that the steam, feedwater, and condensate lines and associated components shall be instrumented during the initial startup testing. Clarify whether these lines and associated components, including safety relief valves and power operated valves and their actuators will be instrumented to measure vibration during testing. Also discuss how this data would be used to demonstrate that short term and long term limits would not be exceeded for the piping and individual components.*

**GE Response**

Refer to Attachment B "ESBWR Startup Acceptance Criteria For Piping" which describes that the steam, feedwater, and condensate lines and associated components shall be instrumented during the initial startup testing, how these lines and associated components, including safety relief valves and power operated valves and their actuators will be instrumented to measure vibration during testing and how this data would be used to demonstrate that short term and long term limits would not be exceeded for the piping and individual components. For example, Paragraph 7.0, Gages required, of the Attachment specifies accelerometers on SRVs and MSIVs, Paragraph 5, Steady State Vibration Criteria discusses long term limits and Paragraph 3.0, Transient Dynamic Loads discusses short-term limits.

**DCD Impact**

No DCD changes will be made in response to this RAI.

**NRC RAI 3.9-68**

*The discussion provided in DCD Tier 2, Section 3.9.2.4 does not specifically state which plant parameters will be monitored during the hold points on the steam, feedwater and condensate systems and components. Discuss the plant parameters which would be monitored during the hold points with respect to the steam, feedwater and condensate systems and components.*

**GE Response**

The plant parameters which would be monitored during the hold points (test conditions) with respect to the steam, feedwater and condensate systems and components are discussed in DCD Tier 2 Subsection 14.2.8.2, General Discussion of Startup Tests, and shown in Attachment A, REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS, tables. It is noted that a detailed test specification will be prepared separately prior to the pre-operation and start-up tests.

**DCD Impact**

No DCD changes will be made in response to this RAI.

**NRC RAI 3.9-70**

*The discussion provided in DCD Tier 2, Section 3.9.2.4 does not provide specific information on the acceptance criteria for monitoring, trending and inspection of the steam, feedwater, and condensate systems during ESBWR startup testing. The staff considers this information highly pertinent in evaluating the potential adverse flow effects, particularly on steam dryers and main steam system components. Discuss the acceptance criteria for monitoring, trending, and conducting the walkdowns and inspections relating to the steam, feedwater, and condensate systems during ESBWR startup tests. Also discuss the actions to be taken if acceptance criteria are not satisfied.*

**GE Response**

Refer to Attachment B "ESBWR Startup Acceptance Criteria For Piping" which provides information on the acceptance criteria for monitoring, trending and inspection of the steam, feedwater, and condensate systems during ESBWR startup testing, including the acceptance criteria for monitoring, trending, and conducting the walkdowns and inspections relating to the steam, feedwater, and condensate systems during ESBWR startup tests, and the actions to be taken if acceptance criteria are not satisfied.

**DCD Impact**

No DCD changes will be made in response to this RAI.

## Attachment A

**REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS**

DCD2 Subsection 14.2.8.2 provides the general discussion of startup tests.

The following tables provide preliminary test hold points for each system. The final test procedures are made available to the NRC 60 days prior to the scheduled date for fuel loading.

**REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS**

| Test Type | Test Condition | Method of Measurement |
|---|---|---|
| Preoperational | | |
| A. Interference to thermal expansion (21-38°C) | A.1 Piping at ambient temperature | A.1.1 Visual |

| | | |
|---|---|---|
| B. Blank | Blank | B.1.1 Blank |
| | | |

## REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS (Continued)

| Test Type | Test Condition | Method of Measurement (Note C1 defines instrumentation type, M, V, S and T) |
|---|---|---|
| Startup | | |
| C. Thermal expansion movements | C.1 Piping at ambient temp (21-38°C) | C.1.1 Test instruments type M |
| | | C.1.2 Visual |
| | C.2 Vessel at 10 ± 1 kg/cm2 gage | C.2.1 Test instruments type M |
| | | C.2.2 Visual |
| | C.3 Vessel at 40 ± 1 kg/cm2 gage | C.3.1 Test instruments type M |
| | | C.3.2 Visual |
| | C.4 Plant at 75 to 100% rated electrical power | C.4.1 Test instruments type M |
| | C.5 Vessel at $70^{+2}_{-5}$ kg/cm2 gage | C.5.1 Test instruments type M |
| | | C.5.2 Visual |

**Note C1 Instrumentation type symbols.**

(a) Many of the dynamic Vibration and thermal Movement transducers have the same locations and directions. LVDT (Lanyard Potentiometer ) is a multiple duty transducer. It can measure thermal movement (M) and dynamic vibration (V) displacement time history. Therefore, M and V can use the same type of gage.

M Thermal movement
V Vibration displacement
S Strain gage
T Temperature gage

**REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS (Continued)**

| Test Type | Test Condition | Method of Measurement (Note C1 defines instrumentation type, M, V, S and T) |
|---|---|---|
| D. Steady state vibration displacements and strains | D.1 Main steam at 25% ± 5% flow and coincident temperature | D.1.1 Test instruments type V |
| | D.2 Main steam at 50% ± 5% of rated flow and oper. temp. | D.2.1 Test instruments type V |
| | D.3 Main steam at 75% ± 5% of rated flow and oper. temp. | D.3.1 Test instruments type V |
| | D.4 Plant at 100% of rated electrical power. | D.4.1 Test instruments type V |
| | | D.4.2 Test instruments type S |
| | | D.4.3 Test instruments type S |

Notes for Tests D.1 through D.4:

D1. Under Test D.4, the steady state strain gages (D.4.3, type S) and the temperature sensors (type T) shall be measured at least once every 5 seconds.

## REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS (Continued)

| Test Type | Test Condition | Method of Measurement (Note C1 defines instrumentation type, M, V, S and T) |
|---|---|---|
| E. Transient vibration displacements and strains and thermal movement of wetwell piping associated with SRV blowdown. | E.1 Turbine control or stop valve closure at 100% generator load rejection | E.1.1 Test instruments type V<br>E.1.2 Test instruments type S |
| | E.2 Discharge of SRVs at 72.1 ± 1 $kg/cm^2$ gage (normal operating pressure) during planned transient tests that result in SRV discharge (RV1 and RV2) | E.2.1 Test instruments type V<br>E.2.2 Test instruments type M<br>E.2.3 Test instruments type S |
| | E.3 Feedwater pump trip at 100% rated electrical power | E.3.1 Test instruments type V<br>E.3.2 Test instruments type S |
| | E.4 Feedwater pump restart following test E.3. | E.4.1 Test instruments type V<br>E.4.2 Test instruments type S |

Notes for Tests E.1 through E.4:

1 E.3 and E.4 test measurements shall be taken during the planned transient testing of the reactor feed pumps. One set of measurements shall be made for each of the various turbine and motor driven pump combinations and start/stop sequences employed during plant startup test operations.
2. Tests E.1 and E.2 may be conducted during the same transient.
3. During Tests E.1 through E.4, the transient strain measurements (type S) shall be taken at a frequency of at least 500 times per second. Temperature sensors, (type T) shall be measured at least once every 5 seconds, except for those on the SRVDL wetwell piping, which shall be measured at a frequency of at least 20 times per second.

**REQUIRED TESTS AND ASSOCIATED SYSTEM CONDITIONS (Continuous)**

| Test Type | Test Condition | Method of Measurement (Note C1 defines instrumentation type, M, V, S and T) |
|---|---|---|
| F. Thermal Stratification | F.1 Maximum feedwater stratification in Loop A or B following a turbine control or stop valve closure at 100% load rejection. See Note 3 and Paragraph 8.1.4.1 | F.1.1 Test instruments type T<br>F.1.2 Test instruments type M<br>F.1.3 Test instruments type S |
| | F.2 Maximum feedwater stratification in Loop A or B at normal shutdown from 100% power to hot standby. See Note 4 and Paragraph 8.1.4.2 | F.2.1 Test instruments type T<br>F.2.2 Test instruments type M<br>F.2.3 Test instruments type S |

Notes for Tests F.1 and F.2:

1 For Tests F.1 and F.2, the feedwater valve alignment shall be such that, to the maximum extent possible within normal plant operating procedures, the cold feedwater flow shall be directed to loop being tested.
2 For Test F.1, start monitoring the instrumentation just prior to the turbine trip. Monitor the instrumentation for at least two hours after the turbine trip to measure the stratification in the lower header. Continue to monitor the instrumentation until the reactor is at approximately 20% power.
3 For Test F.2, monitor the instrumentation throughout the duration of the shutdown operation. Continue to monitor the instrumentation until the reactor is in a hot standby condition and maintain constant rated pressure in the RPV for approximately 2 hours.
4 During Tests F.1 and F.2, the thermal expansion movements of FW line A and FW line B shall be recorded on the thermal expansion movement sensors (type M).
5 During Tests F.1 and F.2, the pipe movement sensors (type M) and the temperature sensors (type T) shall be measured at 1 to 10 minute intervals throughout the feedwater stratification tests. The length of time during which measurements are being taken, and the length of the intervals between the times when measurements are being taken, shall be adjusted based on the rate of change of the temperatures, so that a comprehensive picture of the overall stratification event is obtained, including the worst case stratification conditions. During the times when

measurements are being taken, the pipe movement sensors (type M), the temperature sensors (type T) and the strain gages (type S) shall be measured at least once every 5 seconds.

# Attachment B

# ESBWR STARTUP ACCEPTANCE CRITERIA FOR PIPING.

**Nomenclature**

| | |
|---|---|
| **Pa** | Calculated Maximum Allowable Internal Pressure for a Straight Pipe (at least equal to design pressure) |
| **PD** | Design Pressure |
| **PP** | Peak Pressure or the Operating Pressure Associated with that Transient |
| **$RV_1$** | SRV Opening Loads (Acoustic Wave) |
| **$RV_2I$** | SRV Basemat Acceleration Loads (Inertia Effect) (all valves) |
| **SSEI** | Safe Shutdown Earthquake (Inertia Effect) |
| **$S_m$** | Stress Intensity at Design Temperature |
| **$S_y$** | Yield Strength Value, taken at average fluid temperature of transient under consideration |
| **TE** | Thermal Expansion |
| **TSV** | Turbine Stop Valve Closure Loads |
| **U** | Cumulative Fatigue Usage Factor |
| **WT** | Dead Weight |
| **Rcn** | Ratio factor between the allowable stress and the maximum calculated stress due to dynamic load such as RV1. |
| **C2** | Stress index defined in ASME Table NB-3681(a)-1 |
| **B2** | Stress index defined in ASME Table NB-3681(a)-1 |
| **Mi** | Resultant moment range defined in NB-3653, EQ. 12 |

**1.0 Introduction**

## 1.1 Purpose

The purpose of this document is to provide the acceptance criteria for steady-state vibration, transient dynamic loads and thermal expansion critical piping systems for pre-operational and start-up testing.

During plant pre-operational and startup, the response of critical piping systems is measured by pipe displacement transducers, accelerometers and by strain gauges

The piping system is acceptable if the actual measurements of piping response are within the acceptance limits determined by the calculations made in accordance with these criteria.

Displacement transducers are used to measure pipe movements due to thermal expansion, thermal stratification. Displacement transducers or accelerometers are used for dynamic transients (RV1, RV2 and TSV) and steady-state vibration. Strain gauges are used to measure pipe strains resulting from dynamic transients and steady-state vibration.

## 1.2 Criteria

There are two levels of limits used in comparing the measured test values from displacement gages (lanyard potentiometer), accelerometers and strain gages.

Level 2.

If the piping measured values are "equal to" or "less than" the values set up for Level 2 limit, the piping system is responding in a manner consistent with the predictions, and is therefore acceptable.

Level 1.

Level 1 criteria is determined based on the ASME Code allowable. If Level 1 criteria is exceeded, the test should be on hold or mandatory termination.

**1.3 Applicable Codes**

(1) ASME Code NB-3653.6 Equation 12 stress limit. This is to ensure the maximum expansion stress range in the whole piping system be less than 3Sm.

(2) MEB 3-1 of SRP 3.6.2 special limit for Equation 12 stress to be 2.4 Sm. This is to meet no postulated pipe break criteria.

(3) ASME Code NB-3654 Equation 9 Service Level B limit for transient dynamic loads. The combined stress should be less than 1.8 Sm and 1.5Sy.

(4) ASME OM-SG-1990 Standard, Paragraph 3.2.1. This paragraph specifies the steady state vibration peak stress amplitude limits. For stainless steel, the stress limit is 10,880 psi and for carbon steel, the stress limit is 7,692 psi. If the piping consists of two materials, the lower limit should be used.

**1.4 Documentation**

Prior to the pre-operational and startup testing, GENE formal Startup Test Requirements Specification should be issued. The requirement of instrumentation, acceptance criteria and test hold conditions and associated criteria are defined in the specification.

**2.0 Thermal Expansion (TE) Test Criteria**

The thermal expansion acceptance limit, $D_{Level\ 1}$, for the gauge displacement is to insure the maximum thermal expansion stress in the piping system will not exceed the limit defined in paragraph 1.3(1) and 1.3(2).

## 2.1 Determine the maximum TE stress ($\sigma_{max}$)

PISYS program calculate the thermal expansion for each thermal case. ANSI7 program compute the thermal expansion stress range for all the piping nodes according to the ASME NB-3650 Equation 12. The maximum thermal expansion stress range, $\sigma_{max}$, in the applicable piping system is,

$$\sigma_{max} = C2\ M_i/Z$$

The Allowable Stress ($\sigma_{allow}$) = 3.0Sm. for operating plants.

The Allowable Stress ($\sigma_{allow}$) = 2.4Sm. for ESBWR

## 2.2 Calculate Thermal Expansion stress Ratio, Rthem

$$Rthem = \sigma_{max}/\sigma_{allow}$$

## 2.3. Level 1 displacement limits ($D_{max}$)

Calculate maximum allowable displacement (Level 1) in each of the orthogonal directions at the gauge location are $Dx_{max}$, $Dy_{max}$ and $Dz_{max}$

$$Dx_{max} = Dx_{calc}/Rthem + Tolerance$$

$$Dy_{max} = Dy_{calc}/Rthem + Tolerance$$

$$Dz_{max} = Dz_{calc}/Rthem + Tolerance$$

Tolerance for operating plants is defined as the sum of the following two items:

(a) Temperature distribution= (1/16 in.)
(b) Transducer resolution (1/32 in)

For ESBWR, tolerance = 0.0.

## 2.4 Level 1 Minimum thermal displacement $D_{min}$

The actual thermal expansion displacement can be higher or lower than the actual calculated value*: Allowable deviation from calculated value may be either plus or minus.* Calculate minimum allowable displacement $D_{min}$ in each of the orthogonal directions $Dx_{min}$, $Dy_{min}$ and $Dz_{min}$ are defined below.

Let $\Delta D = D_{max} - D_{calc}$

$D_{min} = D_{calc} - \Delta D$

### 2.5 Level 2 allowable displacement

The calculated thermal displacements are the level 2 displacement criteria.

### 3.0 Dynamic Transient Displacement Limits (0-peak)

## 3.1 Acceptance limit

The dynamic transient acceptance limit for displacement measurement is defined as movement, at the gauge location, which insures the stress due to the dynamic transient, when added to the stress due to pressure and weight will not exceed the code allowable value for Equation 9, at any node in the piping system. Dynamic Transients consist of RV1, RV2 and TSV. RV1 and TSV apply only to the Main steam and SRV discharge piping.

## 3.2 Calculate the maximum stress Ratio, Rcn.

(1) Calculate the maximum allowable stress ($\sigma_{all}$) at Gage Location

$\sigma_{all} = 1.8\ Sm - S_{wt} - S_{press}$ ( ASME III Code) (Eq. 3-1)

Where $S_{wt}$ = Eq (9) Stress due to dead weight

$S_{press}$ = Eq (9) Stress due to pressure

(2) Calculated the Eq 9 maximum bending stress in the piping system.

$\sigma b_{max} = B2\ M_R/Z$, Where: (Eq. 3-2)

$M_R = (Ma^2 + Mb^2 + Mc^2)^{0.5}$
Ma = Torsion Moment
Mb = bending moment in b-axis
Mc = Bending moment in c-axis

$Rcn = \sigma_{all} / \sigma b\ max$

(Eq. 3-3)

## 3.3 Calculate Level 1 zero to peak displacements, D Level 1

Calculate Level 1 zero to peak displacements for each of the three orthogonal directions, Dx, Dy and Dz.

$D_{level\ 1} = (D_{calc}) \times (Rcn) + C$, where C = 0.25 mm or 0.01 inches.

$D_{calc}$ = Calculated displacements at gauge location for each of the three orthogonal directions, Dx, Dy and Dz.

*Note: The "C" value of 0.25 mm is added to account for the effects of free play in the snubbers. Specifications allow a total free play equal to 0.04 in, or 0.02 in., 0 - peak.. Snubber freeplay allows the pipe to move a small distance with being restrained by the snubber.*

**4.0. Transient Dynamic Strain gage limits**

## 4.1 Dynamic Transients:

The description is the same as 3.1.

## 4.2 Calculate the maximum stress Ratio, Rcn

The description is the same as 3.2.

## 4.3 Calculate the Level 1 Acceptance Criteria

(1) Establish predicted bending stress at strain gauge location in the direction of the strain measurement.

$\sigma_{bend\ gage} = C2 \times M_{bend} /(Z)$; where

$M_{bend}$ is the calculated bending moment at the strain gage location and direction

$\varepsilon_{level\ 1} = (\sigma_{bend\ gage}) \times (Rcn)/E$ , where E is modulus of elasticity.

It is noted that the moments use in piping analysis are the maximum SRSS moment from the time history analysis. The criteria use the maximum moment component at the gage location and direction. The differences are shown in PISYS detail output.

**5.0 Steady State Vibration:**

## 5.1 Establish allowable steady state stress ($\sigma$all)

The steady state vibration acceptance limit, **(Strain level 1)**, at the strain gauge location, is to ensure that the maximum vibration stress in the whole piping system is still less than the endurance limit of the piping base material. The endurance limit is defined as $S_{el}/\alpha$, where:

$S_{el} = 0.8\ S_A$ (paragraph 1.3(4))

$S_A$ is the alternating stress at $10^6$ cycles in Fig. I-9.1, or $S_A$ at $10^{11}$ cycles from Fig. I-9.2.2 of ASME Section III,

$\alpha = 1.3$ for Material covered by Fig. I-9.1 and 1.0 for material covered by Fig I-9.2.2.

Base allowable strains on the allowable stress values are,

$\sigma_{all}$ (Stainless Steel) = 0.8 x 13,600/1.0 = 10,880 psi

$\sigma_{all}$ (carbon steel) = 0.8 x 12,500/1.3 = 7692 psi

**5.2 Acceptance limit for steady state vibration**

Calculate the maximum stress in the piping system, $\sigma$max=(C2K2 M/Z) max

Calculate the stress at gage location, $\sigma$gage=(C2K2 Mgage/Z)

Calculate factor for the gage, Factor = $\sigma$allow/ $\sigma$max

Level 1 stress= Factor x $\sigma$gage

**(Strain Level 1)**= (Factor x $\sigma$gage) /(K2x E)

Level 2 strain = $\sigma$gage/ (K2x E)

Note: K2 is peak stress index at gauge location. C2 is excluded from the equation since secondary stress represented by C2 index will be included in the strain gauge measurements.

Detail dynamic analysis method is included in section 6.0.

## 6.0 Steady State Vibration Displacement Limit

The steady state vibration acceptance limit, $Dss_{Level\ 1}$, at the gauge location, is to ensure that the maximum stress in the whole piping system is still less than the endurance limit.

## 6.1 Steady vibration dynamic analysis methods

There are various ways to develop the steady state vibration criteria. One way to develop the criteria is based modal results. For complicated piping system, it is not practical to use modal results. The reason is that it is very complicated and time consuming to develop the modal criteria. After each test, it will take a long time to match the mode shape and frequency with modal criteria. Therefore, the analysis method proposed below will obtain conservative criteria to be used during the test.

### 6.1.1 Dynamic analysis loading

The dynamic analysis input loadings used to develop the steady state criteria should be well represented of the actual loading of the piping system during steady state vibration. For example, the piping connected to pump should include dynamic analysis with motor eccentricity force. If the piping has pump vane passing acoustic wave load, time history analysis including acoustic load should be included. If main steam pipe has subjected to SRV branch pipe acoustic forcing function, the dynamic analysis should includes this function. If the pipe subjected to the broadband flow turbulence or unknown function, 1g uniform response spectra in all three orthogonal directions may be used.

### 6.1.2 Low frequency and high frequency loads

Divide all the forcing functions into two groups, low frequency and high frequency. Low frequency dynamic loading uses the name "SSE" and high frequency uses "RV2" for easier discussion. Different names can be used. In this analysis it is assumed that the maximum high frequency (RV2) 0-peak stress is limited to 50% of the allowable and the other 50% for the low frequency (SSE). Using this method, the maximum stress for SSE and RV2 may not be at the same location, the sum of the stresses will be lower than the allowable. Based on the experience, there is about 20% margin added using this absolute sum method.

### 6.1.3 Snubber Stiffness assumption

Normally there is small free play for the snubbers used in piping system. Typical value is 0.020 inch (0.5 mm). Snubber should not be locked up during steady state vibration. But it may not be true that the snubber has zero stiffness during steady state vibration. To develop steady state displacement criteria, it is more conservative to assume that the snubbers are acting. The displacement criterion based on this assumption will be conservative.

Due to the overly conservatism in the displacement criterion, the Level 1 criteria may be exceeded. In the event that the Level 1 displacement criterion is exceeded, the Level 2 velocity criterion can be used.

Different assumption should be considered for certain loading. For example, "organ pipe" effect for the steam pipes. The first fundamental frequency equals speed of sound in steam/ (2 X length). If the main steam pipe length from RPV to the turbine stop valve is 270 ft. The speed of sound for steam is about 1600 ft/sec. The resonance frequency is (1600/(2x270) = 2.96 Hz). If the first mode is close to 3 Hz assuming snubbers are not locked up, then it is required to include this configuration and loading.

## 6.2 Calculate Rcn for both RV2 and SSE

Calculate the peak bending stress due to both SSE and RV2 for all the piping high stress nodes. Save the maximum stress value and the node number.

$\sigma_{Max} = C2K2(M_R)/Z$, where

$M_R$ = Resultant moment due to SSE and to RV2; $M_R = (Ma^2 + Mb^2 + Mc^2)^{0.5}$

$Rcn = \sigma_{all}/\sigma_{max}$

One Rcn for SSE and another Rcn for RV2

## 6.3 Calculate Allowable Displacements, Dall at the gage node

Calculate Allowable Displacements, Dall, for RV2 and for SSE at displacement gauge location. (Dall = Dcalc x Rcn )

For RV2: $Dall_{RV2}$ = 0.5 x (Dcalc RV2 x Rcn)

For SSE: $Dall_{SSE}$ = 0.5 x (Dcalc SSE x Rcn)

### 6.4 Calculate acceptance criteria (Dss), Level 1

*An acceptance displacement,* ($Dss_{Level\ 1}$), *is calculated for each of these two types of loading and the steady state vibration acceptance criteria is set equal to the average of these two allowable displacements.*

$Dss_{Level\ 1} = (Dall_{RV2} + Dall_{SSE})$

Using the absolute sum method is always conservative.

## 6.5 Establish allowable velocity limits

**6.5.1 Vibration Screening Criteria**

In order to speed up piping vibration data interpretation, a vibration screening criteria is often resorted to. The vibration screening criteria is a very conservative criteria recommended for piping systems by the ASME [Ref. 2]. According to this ASME standard, "Piping systems with peak velocities less than 0.5 ips (inch per second) are considered safe from a vibratory stress viewpoint and require no further analysis". The velocity screening criteria is valid for all frequencies of piping vibrations and can be considered safe from a vibratory stress viewpoint. Where appropriate, this velocity screening criteria is used in this evaluation.

**6.5.2 Vibration velocity criteria**

The dynamic analysis can also be used to develop the velocity criteria when accelerometers are used in the measurements.

The dynamic analysis results obtained the displacements and acceleration values. The equivalent vibration frequency can be obtained from the equations below. Let, D = dynamic analysis calculated displacement

A =dynamic analysis calculated acceleration

A $= D(\omega^2)/386$

Freq $= (1/(2\pi))[Ax386/D]^{1/2}$

V $= D(\omega)$

Similar procedures to obtain the displacement criteria can be used to develop the velocity criteria. If accelerometer is used for the measurement, it should be converted to velocities and displacements. Both of the velocity and displacement criteria should be compared. This is to verify the forcing functions in the dynamic analysis are reasonable.

**7.0 Gages required.**

The following gages are required for each line inside the containment. The measured for acoustic load is not included. (Note 1)

| Pipe lines | Gage type | Location | Number of gages | Remark |
|---|---|---|---|---|
| Each Main steam (2) | Displacement (LVDT) | MS pipe | 4 | Test specification specify exact locations |
| | Accelerometers (Acc) | SRV valve | 6 | Same as above |
| | Accelerometers (Acc) | MSIV valve | 6 | Same as above |
| | Strain gages (SG) | SRV branch | 2 | Same as above |
| Each feedwater | Displacement (LVDT) | FW pipe | 6 | Same as above |
| | Strain gages (SG) | FW pipe | 6 | Same as above |
| Condensate | Will be provided after analysis performed | | | Same as above |

Note 1 :All the instrumentation set up will insure that the piping displacements and the vibration stresses of the piping system are within the ASME allowable limits. Detail gage setup and number of gages may be changed during the actual design process. The gages for all other systems, such as condensate piping, will be instrumented after the stress analysis are completed and to determine the most critical locations.

Note 2 : The instrumentation does not include the strain gage setup for dryer to measure the acoustic resonance in the main steam pipe due to the SRVs. These measurements use pair of strain gages in the circumferential direction of the pipe. The gages are located before and after the valves. The gages are located on the pipe free from stress concentrations.