GE Nuclear Energy

General Electric Company
175 Curtner Avenue, San Jose, CA 95125

GE-NE-0000-0032-1827-01
Class I
DRF Section 0000-0039-8548
April 2005

Quad Cities Replacement Steam Dryer

Damping Values for Hood and Skirt Flow Induced Dynamic Analysis

Prepared by:
Richard Wu

Manager:
Mike Schrag
Structural Analysis &
Hardware Design

NON PROPRIETARY NOTICE

This is a non proprietary version of the document GE-NE-0000-0032-1827-01P, 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

The only undertakings of the General Electric Company (GENE) with respect to the information in this document are contained in the contract between EXELON and GENE, and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than EXELON or for any purpose other than that for which it is intended, is not authorized; and with respect to any unauthorized use, GENE makes no representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe upon privately owned rights.

1. Summary

For the elastic dynamic analysis and design of the steam dryer subjected to fluid induced oscillating loading at CLTP and EPU conditions, a modal damping value of [[ ]] This damping value is selected mainly based on the review of four references: (1) Regulatory Guide 1.61- Damping Values for Seismic Design of Nuclear Power Plants (2) "Kashiwazaki-6 Steam Dryer Hammer Test Final Repost" (3) QC New Steam Dryer Hammer Test Results, and "Tokai-2 Steam Dryer Vibration and Valve Closure Response". Detail of this assessment is given in Appendix 1.

A modal damping value of [[ ]] of the QC replacement steam dryer flow induced dynamic response analysis. This damping value is selected mainly based on two references: (1) Regulatory Guide 1.61- Damping Values for Seismic Design of Nuclear Power Plants and (2) QC Replacement Steam Dryer Hammer Test Results. Detail of this assessment is given in Appendix 2.

Based on the present assessment, the use of critical damping values [[ ]]

Appendix 1

Damping Value for Steam Dryer Hood

Flow Induced Dynamic Analysis

SUMMARY

For the elastic dynamic analysis and design of the steam dryer subjected to fluid induced oscillating loading at CLTP and EPU conditions, a modal damping value of 1% of critical damping is recommended to be used for all modes of the hood. This damping value is selected mainly based on the review of four references: (1) Regulatory Guide 1.61- Damping Values for Seismic Design of Nuclear Power Plants (Reference 1), (2) "Kashiwazaki-6 Steam Dryer Hammer Test Final Repost" (Reference 2), (3) QC New Steam Dryer Hammer Test Results (Reference 3), and "Tokai-2 Steam Dryer Vibration and Valve Closure Response" (Reference 4).

DISCUSSION

A structural dynamic system, such as steam dryer, is generally subjected to three kinds of damping mechanism: material damping, structural damping and fluid damping. These damping mechanisms cause the energy to dissipate while the structural system is responding to a dynamic loading. In performing an elastic dynamic response analysis, this energy dissipation is typically accounted for by specifying an amount of viscous damping or the percent of critical damping, if modal analysis is employed.

In practical structures, the damping and energy-loss mechanism are very complex and seldom fully understood; thus it is not feasible to determine with analytical means the exact damping values. In common practice, the damping values are evaluated directly by experimental methods.

Test measurements have shown that the magnitude of the structural damping depends not only on the type of joints or connections within the structure, but also on the magnitude of deformation experienced; the larger the structure deforms, the larger the structural damping value is. As shown in Figure 1 (Reference 5), the damping increases with vibration amplitude, indicating that local yielding may be taking place.

Figure 1 (Reference 5)

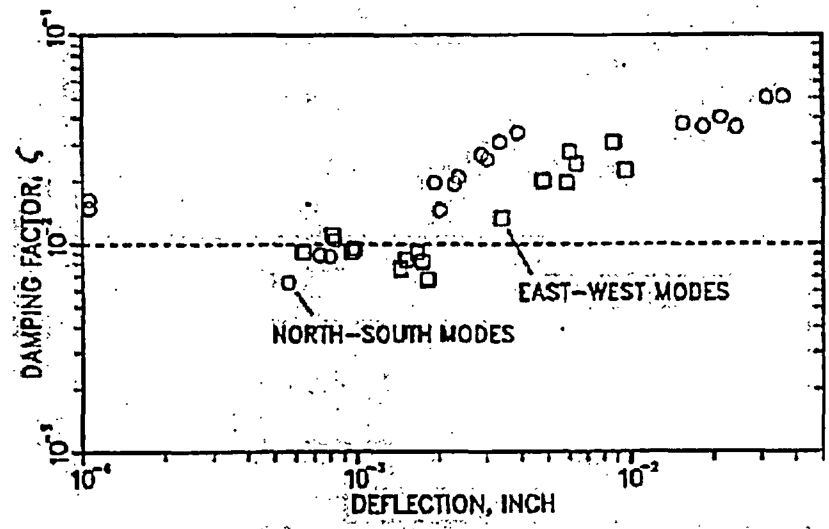

Fig. 8-20 Damping of a nuclear power plant steam generator as a function of amplitude of vibration (Hart and Ibanez, 1973).

In the present assessment, the damping values used in the design of nuclear power plants (Reference 1), damping values obtained from hammer tests of K-6 steam dryer (Reference 2) and QC new steam dryer (Reference 3), and steam dryer vibration responses due to valve closure (Reference 4) are reviewed. Based on these references, a conservative damping value of 1% is recommended for the steam dryer hood flow induced vibration analysis.

(1) Regulatory Guide 1.61- Damping Values for Seismic Design of Nuclear Power Plants (Reference 1):

In seismic design of nuclear power plants, modal damping values are recommended in NRC Regulatory Guide 1.61. Table 1 lists the recommended damping values for various types of structures and piping.

Table 1 Damping Values (Reference 1)
(Percent of Critical Damping)

Structure or Component	Operating Basis Earthquake or ½ Safe Shutdown Earthquake	Safe Shutdown Earthquake
Equipment and large-diameter piping systems, pipe diameter greater than 12 inch	2	3
Small-diameter piping systems, pipe diameter equal to or less than 12 inch	1	2
Welded steel structures	2	4
Bolted Steel Structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

The Regulatory Guide states that the modal damping values as given in Table 1 should be used for the viscous modal damping for all modes considered in an elastic spectral or time-history dynamic seismic analysis of the Seismic Category I structures or components as specified in the table.

The Regulatory Guide also states that if the maximum combined stresses due to static, seismic, and other dynamic loading are significantly lower than the yield stress and ½ yield stress for SSE and ½ SSE, respectively, in any structure or component, damping values lower than those specified in Table 1 should be used for that structure or component to avoid underestimating the amplitude of vibrations or dynamic stresses.

The Regulatory Guide further states "Damping values higher than the ones delineated in Table 1 of this guide may be used in a dynamic seismic analysis if documented test data are provided to support higher values"

Note that the steam dryer is of the welded steel structural type. Assuming that for the steam dryer, the maximum combined stresses due to static, seismic and other dynamic loadings are lower than the yield stress, a [[

]] This is to avoid underestimating the amplitude of vibrations or dynamic stresses.

For the seismic analysis of nuclear power plants, the structural modal frequencies of interest are typically below 30 Hz. However, for a steam dryer subjected to fluid induced dynamic loading, the structural modal frequencies of interest could be up to 250 Hz. Laboratory tests have shown that the damping values are somewhat independent of the structural modal frequencies, as illustrated in Figure 2 (Reference 5). Note in Figures 2 that the upper bound frequency is about 600 Hz. Thus, for the present steam dryer dynamic analysis, [[

]]

Figure 2 (Reference 5)

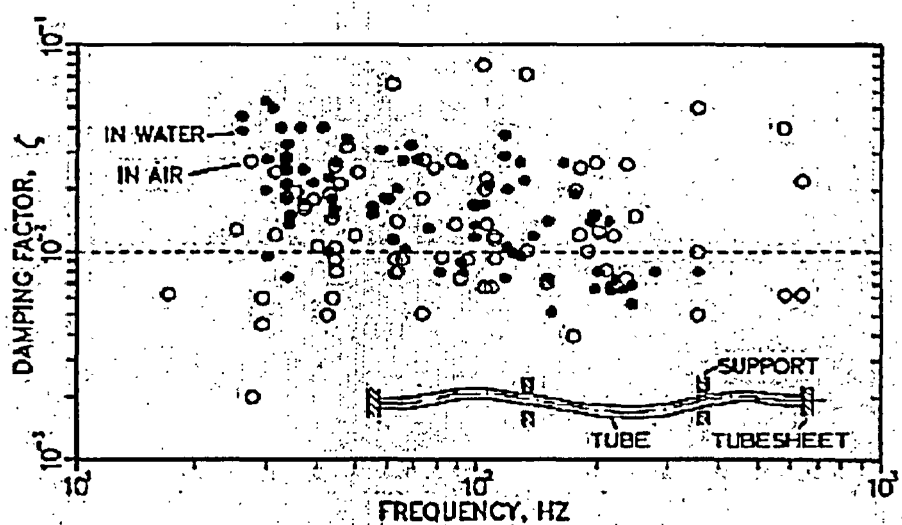

Fig. 8-19 Damping of multi-span heat-exchanger tubing (Pettigrew et al., 1986).

(2) "Kashiwazaki-6 Steam Dryer Hammer Test Final Repost" (Reference 2)

An impact hammer test was conducted on the steam dryer at Kashizazaki-6 Site (a ABWR plant) in September 1995. The test was conducted at an ambient environment condition. The primary objective of the test was to identify the as-built natural vibration modal frequencies and mode shapes. The identification of modal damping value was not included in the test objective.

For the present assessment of the modal damping value of the steam dryer, the original hammer test frequency response spectrum data were retrieved and reviewed first. The damping value was then calculated from the frequency-response curve using the half-power (bandwidth) method (Reference 6).

Shown in Figure 3 is a typical hammer test frequency-response spectrum at the hood of the steam dryer.

[[

]]

[[

]]

It should be noted that these damping values may not be directly applicable to the forced dynamic response analysis of the steam dryer. As mentioned previously, the actual damping value depends on the severity of the deformation of the steam dryer which, under the reactor operating environment are normally much higher then those induced by the hammer test.

This review of Kashizazaki-6 steam dryer impact hammer test may serve to confirm the reasonableness of using a [[
]]

(3) "QC Replacement Steam Dryer Hammer Test Results" (Reference 3)

An impact hammer test is being conducted on the QC new steam dryer. The primary objective of the test is to identify the as-build natural vibration modal frequency, mode shape and modal damping.

Shown in Table 2 are hammer test measured modal frequencies and damping values of the dryer hood panel.

[[

]]

It should be noted that these damping values may not be directly applicable to the forced dynamic response analysis of the steam dryer. As mentioned previously, the actual damping value depends on the severity of the deformation of the steam dryer which, under the reactor operating environment, are normally much higher then those induced by the hammer test.

(4) "Tokai-2 Steam Dryer Vibration and Valve Closure Response" (Reference 4)

[[

]]

For the present assessment of the modal damping value of the steam dryer, the recorded transient (time history) responses were reviewed first. The damping value was then calculated from the transient-response curve using the logarithmic decrement (free-vibration decay) method (Reference 6).

Shown in Figures 4 and 5 are the typical strain-time history records at the dryer hood for MSIV and TSV closures, respectively.

[[

]]

The peak measured strains, as shown in Figures 4 and 5, [[ ]] respectively. Under the normal reactor operating environment, [[ ]] Using the logarithmic decrement method, [[ ]]

This review of Tokai-2 steam dryer MSIV and TSV closure test data has shown that [[ ]]

REFERENCES

1. U.S. Nuclear Regulatory Commission Regulatory Guide 1.61 – Damping Values for Seismic Design of Nuclear Power Plants, October 1973.

2. "Kashiwazaki-6 Steam Dryer Hammer Test Final Repost" GENE-F4100056-2, DRF F41-00056, February 1997.

3. "Test and Analysis Report -Quad Cities New Design Steam Dryer #1 Experimental Modal analysis and Correlation with Finite Element Results" LMS, April 2005.

4. "Tokai-2 Steam Dryer Vibration and Valve Closure Response" NEDE-24814, CalssIII, June 1980.

5. Flow Induced Vibration, 2nd Edition, R. D. Blevins, Krieger Publishing Company, 1990.

6. Dynamics of Structures, R. W. Clough and J Penzien, McGraw- Hill Inc., 1975

Appendix 2

Damping Value for Steam Dryer Skirt

Flow Induced Dynamic Analysis

SUMMARY

A [[ ]] the skirt of the QC replacement steam dryer flow induced dynamic response analysis. This damping value is selected mainly based on two references: (1) Regulatory Guide 1.61- Damping Values for Seismic Design of Nuclear Power Plants and (2) QC Replacement Steam Dryer Hammer Test Results.

DISCUSSION

(1) Regulatory Guide 1.61- Damping Values for Seismic Design of Nuclear Power Plants (Reference 1):

In seismic design of nuclear power plants, modal damping values are recommended in NRC Regulatory Guide 1.61. Table 1 lists the recommended damping values for various types of structures and piping.

Table 1 Damping Values (Reference 1)
(Percent of Critical Damping)

Structure or Component	Operating Basis Earthquake or ½ Safe Shutdown Earthquake	Safe Shutdown Earthquake
Equipment and large-diameter piping systems, pipe diameter greater than 12 inch	2	3
Small-diameter piping systems, pipe diameter equal to or less than 12 inch	1	2
Welded steel structures	2	4
Bolted Steel Structures	4	7
Prestressed concrete structures	2	5
Reinforced concrete structures	4	7

The Regulatory Guide states that the modal damping values as given in Table 1 should be used for the viscous modal damping for all modes considered in an elastic spectral or time-history dynamic seismic analysis of the Seismic Category I structures or components as specified in the table.

The Regulatory Guide also states that if the maximum combined stresses due to static, seismic, and other dynamic loading are significantly lower than the yield stress and ½ yield stress for SSE and ½ SSE, respectively, in any structure or component, damping values lower than those specified in Table 1 should be used for that structure or component to avoid underestimating the amplitude of vibrations or dynamic stresses.

The Regulatory Guide further states "Damping values higher than the ones delineated in Table 1 of this guide may be used in a dynamic seismic analysis if documented test data are provided to support higher values"

Note that the steam dryer skirt is of the welded steel structural type, and as tabulated in Table 1, 2% and 4% of critical damping values are used for the OBE and SSE analyses, respectively. Also, The lower portion of the skirt is submerged in water. The damping mechanism due to the fluid damping would be higher at the submerged portion of the skirt than that at the other un-submerged steam dryer components. [[

]]

(2) "QC Replacement Steam Dryer Hammer Test Results" (Reference 2)

An impact hammer test is being conducted on the QC replacement steam dryer. The primary objective of the test is to identify the as-build natural vibration modal frequency, mode shape and modal damping.

Shown in Table 2 are hammer test measured modal frequencies and damping values of two skirt panels: one on the 90-degree side and the other on the 270-degree side of the steam dryer.

[[

]]

The dynamic stress response of the dryer skirt to flow induced vibration (FIV) load has also been calculated. The corresponding frequency content of the calculated stress response is shown in Figure 1. [[

]]

Figure 1 Dryer Skirt Stress Response to Flow Induced Dynamic Load

[[

]]

[[

]]

It should be noted that these hammer test calculated damping values are conservative compared with that during the forced dynamic response environment of the steam dryer. This is because, as mentioned previously, the actual damping value depends on the severity of the deformation of the steam dryer, and hammer test induced deformations are normally much smaller than the deformation under the reactor operating environment. Shown in Figure 2 are typical hammer hit input time history and the corresponding acceleration and strain response time histories.

Figure 2 Hammer Test Input and Response Time Histories

[[

]]

As shown in Figure 2, the hammer test dominant responses are at lower modes and the peak strain [[ ]] Under the normal reactor operating [[ ]]

In summary, the damping values used for seismic design of nuclear power plants (Reference 1) and damping values obtained from steam dryer hammer tests (Reference 2) are reviewed. [[ ]]

REFERENCES

1. U.S. Nuclear Regulatory Commission Regulatory Guide 1.61 – Damping Values for Seismic Design of Nuclear Power Plants, October 1973.

2. "Test and Analysis Report - Quad Cities New Design Steam Dryer #1 Experimental Modal analysis and Correlation with Finite Element Results" LMS, April 2005.

ENCLOSURE 2

ATTACHMENT 3

"Quad Cities Unit 2 Nuclear Power Plant Dryer Vibration Instrumentation Uncertainty," GE-NE-0000-0037-1951-01, Revision 0, Non-Proprietary, dated April 2005