Hope Creek Generating Station
Facility Operating License NPF-57
Docket No. 50-354

Extended Power Uprate

EPU Conditions in the Main Steam Lines at Hope Creek Unit 1: Additional Subscale Four Line Tests
C.D.I. Technical Note No. 07-01NP

This Report Does Not Contain Continuum Dynamics, Inc. Proprietary Information

C.D.I. Technical Note No. 07-01NP

EPU Conditions in the Main Steam Lines at Hope Creek Unit 1: Additional Subscale Four Line Tests

Revision 0

Prepared by

Continuum Dynamics, Inc.
34 Lexington Avenue
Ewing, NJ 08618

Prepared under Purchase Order No. 4500378760 for

Nuclear Business Unit, PSEG Nuclear LLC
Materials Center, Alloway Creek Neck Road
Hancocks Bridge, NJ 08038

Approved by

Alan J. Bilanin

Reviewed by

Milton E. Teske

January 2007

Executive Summary

As part of the engineering effort in support of power uprate at Hope Creek Unit 1 (HC1), Continuum Dynamics, Inc. (C.D.I.) undertook a subscale examination of the standpipe/valve geometry on two of the four main steam lines, in an effort to validate the frequency onset at which flow induced vibration, resulting from standpipe/valve flow resonance, could potentially impact steam dryer loads. In this study [1] C.D.I. constructed a nominal one-fifth scale model of a single main steam line (prototypical of main steam lines A and D) at HC1, from the reactor vessel main steam line nozzle to beyond the standpipes, using seamless steel pipe with full penetration welds. This rig was used to test the as-built configuration of standpipes and Target Rock valves, and did not predict SRV standpipe resonance at Current Licensed Thermal Power (CLTP), as confirmed by in-plant data. These data suggested that EPU conditions would be past excitation onset, and that this loading should receive further evaluation, and possible mitigation.

As part of a subsequent effort [2], C.D.I. constructed a nominal one-eighth scale model of the complete steam delivery system at HC1, from the steam dome to the turbine, with PVC pipe, with the objective of estimating the steam dryer loads at higher power. Simulations were conducted for a wide range of main steam line flow velocities, from below CLTP conditions to well above Extended Power Uprate (EPU) conditions.

In the present effort, discussed herein, additional tests were run in the one-eighth scale test facility, in an effort to compare with the previous one-fifth scale test results and refine the flow speed at CLTP conditions. These results confirmed that flow conditions run during the one-eighth scale tests, as reported in [2], were high by 14%. This reduction resulted from non-prototypical frictional losses in the one-eighth scale rig.

This effort provides PSEG with subscale test data that quantify the level of excitation to be expected at HC1 at EPU conditions, and reduces the conservatism in the previous one-eighth scale EPU load.

Table of Contents

1. Introduction

Data previously taken on the one-eighth scale model of Hope Creek Unit 1 (HC1) included pressure time histories in the four main steam lines at 0.8×CLTP, 0.9×CLTP, CLTP, 1.05×CLTP, and 1.15×CLTP (and at higher power levels). Subsequent analyses on these data assumed that the most representative flow speed for CLTP (Current Licensed Thermal Power) conditions in the plant occurred at CLTP conditions in the scale model as well, as the orifice diameters at the ends of the main steam lines were sized so as to recover the CLTP Mach number anticipated at the entrance to the main steam lines at the steam dome. With the determination of CLTP conditions, EPU (Extended Power Uprate) conditions would occur at 1.15×CLTP in the scale model. These two scaled power levels (CLTP and 1.15×CLTP) were reported in [2] and used to develop hydrodynamic loads as discussed in [3], which were used with a finite element model of the HC1 dryer to predict stresses as discussed in [4].

The results of these tests showed no SRV standpipe resonance at 0.8×CLTP but SRV standpipe resonance at 0.9×CLTP. Since an analysis of the in-plant data showed no SRV standpipe resonance at CLTP conditions [3], it was suggested that additional tests be undertaken to refine the subscale test Mach number to that which more accurately corresponds to the in-plant main steam line flow Mach number. To do so, the following approach was suggested.

[[

(3)]]

[[

(3)]]

[[

(3)]]

This report summarizes the additional test results on the one-eighth scale model of the HC1 plant with four main steam lines to obtain steam dryer loads which more accurately reflect EPU (115% CLTP) conditions.

2. Objectives

Additional tests on the one-eighth scale facility simulating HC1 were conducted to achieve the following goals:

1. Refine the Mach number used in the one-eighth scale facility so as to match the CLTP Mach number determined in the plant.

2. Generate an EPU load consistent with 1.15×CLTP results, in anticipation of a finite element stress analysis of the steam dryer.

3. Technical Approach

The one-eighth scale test facility simulating HC1 was used for the additional tests. This facility and its instrumentation and test procedures were discussed in [2], including discussions of the standpipe excitation mechanism, scaling laws, and test design. It was also shown in [2] that for the Hope Creek 1.0/8.27 scale tests, the frequencies measured in the subscale facility are to be multiplied by 0.176 to obtain full-scale frequencies, while in [1] it was shown that for the Hope Creek 1.0/5.87 scale tests, the multiplication factor is 0.248.

It was also shown in [1] that acoustic pressures at fixed Mach numbers scale with the dynamic pressure in the system i.e., $q = \frac{1}{2}\rho U^2$, where ρ is the air density and U is the air speed in the main steam lines, and consequentially scale with the system pressure.

CLTP and EPU conditions correspond to main steam line Mach numbers of 0.0913 and 0.1050, respectively, as estimated from in-plant data supplied by PSEG, and discussed in [1]. As will be shown below, these Mach numbers are the Mach numbers at the standpipes in the plant.

Typically, for CLTP conditions, for example, the previous one-eighth scale tests [2] set the entrance Mach number to the main steam lines to be representative of the in-plant Mach number. [[

(3)]]

[[3.1

(3)]]

[[3.2

(3)]]

[[

(3)]]

3.3 Use of One-Fifth Scale Test Results

The original one-fifth scale test facility [1] was constructed from seamless steel pipe, and modeled one main steam line at HC1. [[

(3)]]

[[

(3)]]

[[

(3)]]

4. Test Matrix

Table 4.1. HC1 Four-Line Test Matrix (Initial) with Differential Pressure Transducer Measurements

Test Number	Date	Test Run
hc-f480-03	12/08/06	CLTP(U)
hc-f480-04	12/08/06	0.8×CLTP(U)
hc-f480-05	12/08/06	1.15×CLTP(U)
hc-f480-06	12/11/06	1.15×CLTP(U)
hc-f480-08	12/11/06	1.05×CLTP(U)
hc-f480-09	12/11/06	0.9×CLTP(U)
hc-f480-10	12/11/06	0.9×CLTP(U)
hc-f480-11	12/11/06	CLTP(U)
hc-f480-12	12/11/06	0.8×CLTP(U)
hc-f480-13	12/11/06	1.05×CLTP(U)
hc-f480-14	12/12/06	1.05×CLTP(U)
hc-f480-15	12/12/06	CLTP(U)

Table 4.2. HC1 Four-Line Test Matrix (Additional) with Standpipe Pressure Measurements

Test Number	Date	Test Run
hc-f480-16	12/21/06	CLTP(U)
hc-f480-17	12/22/06	0.8×CLTP(U)
hc-f480-18	12/22/06	0.9×CLTP(U)
hc-f480-19	12/26/06	0.9×CLTP(U)
hc-f480-20	12/26/06	0.8×CLTP(U)
hc-f480-21	12/29/06	CLTP(U)
hc-f480-22	01/02/07	0.86×CLTP(U)
hc-f480-23	01/02/07	0.86×CLTP(U)

Table 4.3. HC1 Four-Line Test Matrix (Additional) with Main Steam Line Pressure Measurements

Test Number	Date	Test Run
hc-f480-24	01/04/07	0.86×CLTP(U)
hc-f480-25	01/04/07	0.86×CLTP(U)

5. Results and Discussion

Twelve runs were undertaken initially to quantify the pressure drop between the entrance to the main steam lines and the standpipes. [[

(3)]]

To prevent confusion and to differentiate between the flow conditions established in [2] in contrast with the flow conditions established herein, the following convention will be used in and after Section 4 of this report:

> When referring to the test runs performed in [2] for calculating Mach number, "(U)" will be added behind "CLTP". For example, in Tables 4.1 to 4.3, "CLTP(U)" designates the test run labeled "CLTP" in [2], and the added "(U)" clarifies that this flow condition is uncorrected. When referring to flow conditions as revised in this report, the word "revised" will be added before the flow condition, as for example, "revised CLTP".

5.1 Comparison with One-Fifth Scale Test Results

[[

(3)]]

5.2 One-Eighth Scale Standpipe Measurements

[[

(3)]]

Appendix A includes the ten sets of PSD plots that were used to generate Figure 5.2. The revised [[

(3)]]

[[

(3)]]

6. Steam Dryer Load

The additional testing summarized above demonstrated that the original one-eighth scale test results provided overly conservative steam dryer loadings, since they represented higher flow conditions than measured in the one-fifth scale facility. The following corrections are then made:

[[

(3)]]

Since [4] provided structural evaluations based on the original one-eighth scale test results, it can now be seen that the CLTP(U) analysis in [4] can be used as the revised analysis for EPU conditions.

Additional one-eighth scale tests were conducted (Table 4.3) to compare predicted dryer loads between the revised CLTP conditions and the CLTP(U) conditions (which now represent the revised EPU conditions). The resulting PSD plots are shown in Appendix B. Figure 6.1 compares the low resolution load generated by the acoustic circuit model for these two loads. [[

(3)]]

[[

(3)]]

7. Conclusions

[[

(3)]]

With these corrections, the previous loads for CLTP conditions [2] bound the proposed power uprate to 115% of CLTP conditions. Consequently, the structural analysis performed for CLTP(U) conditions in [4] can be used as the structural analysis for revised EPU conditions. This reference will be revised to reflect this information.

[[

(3)]]

8. References

1. Continuum Dynamics, Inc. 2005. Onset of High Frequency Flow Induced Vibration in the Main Steam Lines at Hope Creek Unit 1: A Subscale Investigation of Standpipe Behavior (Rev. 0). C.D.I. Report No. 05-31.

2. Continuum Dynamics, Inc. 2006. Estimating High Frequency Flow Induced Vibration in the Main Steam Lines at Hope Creek Unit 1: A Subscale Four Line Investigation of Standpipe Behavior (Rev. 1). C.D.I. Report No. 06-16.

3. Continuum Dynamics, Inc. 2006. Hydrodynamic Loads on Hope Creek Unit 1 Steam Dryer to 200 Hz (Rev. 2). C.D.I. Report No. 06-17.

4. Continuum Dynamics, Inc. 2006. Stress Analysis of the Hope Creek Unit 1 Steam Dryer at CLTP and EPU Conditions Using 1/8th Scale Model Pressure Measurement Data (Rev. 0). C.D.I. Report No. 06-27.

5. Shapiro, A. H. 1953. The Dynamics and Thermodynamics of Compressible Fluid Flow. Volume I. John Wiley and Sons: New York. Chapter 6.

6. Bliss, D. B., T. R. Quackenbush and M. E. Teske. 1982. Computational Simulation of High-Speed Steady Homogeneous Two-Phase Flow in Complex Piping Systems. *Journal of Pressure Vessel Technology* 104: 272-277.

7. Continuum Dynamics, Inc. 2006. Bounding Methodology to Predict Full Scale Steam Dryer Loads from In-Plant Measurements (Rev. 3). C.D.I. Technical Note No. 05-28P.

[[

Appendix A: Additional PSD Results

(3)]]

[[

(3)]]

[[

[(3)]]]

[[

[3]]]

[[

Appendix B: One-Eighth Scale Test Data at 0.86×CLTP

(3)]]

[[

(3)]]

[[

[3]]]

[[

[3]]]

[[

[3]]]