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March 31, 2005

Docket No. 50-271
BVY 05-034
TAC No. MC0761

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: **Vermont Yankee Nuclear Power Station**
Technical Specification Proposed Change No. 263 – Supplement No. 26
Extended Power Uprate – Steam Dryer Analyses and Monitoring

References: 1) Entergy letter to U.S. Nuclear Regulatory Commission, "Vermont Yankee Nuclear Power Station, License No. DPR-28 (Docket No. 50-271), Technical Specification Proposed Change No. 263, Extended Power Uprate," BVY 03-80, September 10, 2003

This letter provides additional information in support of the application by Entergy Nuclear Vermont Yankee, LLC and Entergy Nuclear Operations, Inc. (Entergy) for a license amendment (Reference 1) to increase the maximum authorized power level of the Vermont Yankee Nuclear Power Station (VYNPS) from 1593 megawatts thermal (MWt) to 1912 MWt conditions.

In support of Entergy's application for extended power uprate (EPU) at VYNPS, Entergy and its contractors have performed a rigorous structural analysis of the steam dryer that demonstrates its acceptable performance under EPU conditions. This analysis considered the structural modifications performed on the steam dryer during the spring 2004 refueling outage and incorporated the latest industry methodologies in computational fluid dynamics and acoustical modeling. As further assurance of structural integrity, a steam dryer monitoring plan is being proposed with the implementation of strict operational and surveillance requirements during EPU power ascension.

This submittal provides Entergy's basis for the conclusion that the modified VYNPS steam dryer will perform its intended function at EPU conditions. Although the steam dryer performs a non-safety-related function, it must maintain its structural integrity to preclude the generation of loose parts that might have an adverse interaction with safety-related components. The submittal also provides responses to questions posed by the NRC staff in requests for additional information, vendor audits, and public meetings about the analysis techniques employed by Entergy. Those questions generally refer to sources of steam dryer loads, methodology validation, and input parameters for the analyses.

APO1

Analysis Methodology and Results

This submittal describes the methods used by Entergy to predict steam dryer fluctuating pressure loads and evaluate the capability of the VYNPS modified steam dryer to withstand those loads. This analysis includes the following features:

- An acoustic circuit model of the VYNPS steam dryer, vessel head and main steam system that uses plant-specific main steam system pressure measurements for input.

- A benchmark test using a subscale model that demonstrates the ability of the acoustic circuit methodology to use measurements from the main steam system to predict steam dryer loads.

- A diverse computational fluid dynamics (CFD) technique to evaluate the effects of vortex shedding on the steam dryer.

- A finite element model (ANSYS) of the VYNPS steam dryer representing the combined acoustic and CFD load sources to develop overall fluctuating stresses on the steam dryer.

- The results obtained from the application of the methods used by Entergy demonstrate that the steam dryer loads are low and the modified VYNPS steam dryer has significant margin to the fatigue endurance limit.

Steam Dryer Monitoring Plan

The VYNPS Steam Dryer Monitoring Plan will verify acceptable steam dryer performance and includes the following elements:

- Pre-determined steam dryer performance criteria and actions to be taken pursuant to the requirements of a license condition.

- A controlled power ascension process with limits on power increases and hold-points at predefined power levels to monitor plant performance for extended periods.

- Measuring main steam system fluctuating pressure for comparison in the frequency domain to the fatigue stress endurance limit to ensure that steam dryer loadings remain below limits and structural integrity is maintained. Entergy has identified the theoretical acoustic sources in the VYNPS main steam system and will determine if these sources are excited at higher steam flows during EPU conditions.

- Monitoring of moisture carryover to verify the structural integrity of the steam dryer during reactor power operations.

- Monitoring of other plant parameters including main steam pressures and flow rates that provide supplemental indications of steam dryer performance.

Operating Experience and Facility Comparison

Entergy has closely monitored industry operating experience, including the most recent Quad Cities steam dryer inspection results, and has actively participated in industry efforts to evaluate and mitigate the effects of EPU loads on steam dryers. Through its examination of industry experience, Entergy has concluded that:

- The current analytical model yields results that are consistent with industry experience at EPU conditions to date, in cases where severe steam dryer degradation either was or was not experienced.

- Comparisons between VYNPS and other facilities that have operated successfully at EPU conditions for an extensive period support Entergy's conclusion that the expected performance of the VYNPS steam dryer is well bounded by operating experience.

Ongoing Steam Dryer Inspection Program

Entergy has committed to inspect the VYNPS steam dryer during each of the next three refueling outages. Assuming a station power uprate in September 2005, the first opportunity for inspection will be during RFO 25, scheduled during the 4th quarter of 2005. Having sufficient run time at EPU prior to this outage would be invaluable in establishing VYNPS-specific operating experience. Steam dryer structural integrity during future operating cycles will be confirmed based on the outage visual inspection, which will detect the onset of any flow induced vibration fatigue indications.

Summary

The attachments to this letter are as follows:

Attachment	Description
1	Executive Summary
2	Steam Dryer Monitoring Plan (with proposed license condition)
3	CDI Report 04-09, Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes (Proprietary Information)
4	VY-RPT-05-00006 VYNPS Acoustic Model Benchmark- Dryer Acoustic Load Methodology
5	GE-NE-0000-0038-0936P Vermont Yankee Nuclear Power Station Modified Steam Dryer Stress Analysis (Proprietary Information)
6	GE-NE-0000-0038-0936-NP Vermont Yankee Nuclear Power Station Modified Steam Dryer Stress Analysis (Non-Proprietary Information)
7	Technical Memorandum No. 05-06, Analysis of Steam Dryer Differential Pressure Loads at Vermont Yankee
8	Affidavit (Continuum Dynamics, Inc.)

The Executive Summary (Attachment 1) describes the methods and analyses (Attachments 3 through 7) used to demonstrate that the VYNPS steam dryer will maintain its structural integrity at EPU conditions. To verify its integrity, a steam dryer monitoring plan with a proposed license condition is presented in Attachment 2.

The analytical methodology and analyses presented in Attachments 3 and 5 are Proprietary Information as defined by 10CFR2.390 and should be handled in accordance with the provisions of that regulation. Attachment 3 is considered to be Proprietary Information in its entirety. Attachment 5 is presented as a non-proprietary version in Attachment 6. Affidavits attesting to the proprietary nature of the documents are provided as Attachment 8 for Continuum Dynamics, Inc. and incorporated into Attachment 5 for General Electric Company.

In summary, Entergy believes that the analytical methods developed to predict and monitor pressure loads on the steam dryer, coupled with the detailed steam dryer monitoring plan and license condition, provide reasonable assurance that the steam dryer will function safely at EPU conditions.

Entergy stands ready to support the NRC staff's review of this submittal and suggests a meeting at your earliest convenience to provide an overview of the comprehensive approach taken to develop the steam dryer analysis and monitoring program and to facilitate the understanding of the information provided. Entergy will be prepared for any technical discussions that are warranted based on the NRC staff's review of the information provided.

There are no new regulatory commitments contained in this submittal. However, acceptance of the license condition proposed in Attachment 2 hereto will result in the actions proposed in the Attachment with respect to steam dryer monitoring becoming regulatory commitments or obligations.

This supplement to the license amendment request provides additional information to clarify Entergy's application for a license amendment and does not change the scope or conclusions in the original application, nor does it change Entergy's determination of no significant hazards consideration.

If you have any questions or require additional information, please contact Mr. James DeVincentis at (802) 258-4236.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on March 31, 2005.

Sincerely,

Jay K. Thayer
Site Vice President
Vermont Yankee Nuclear Power Station

Attachments (9)

cc: Mr. Richard B. Ennis, Project Manager
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Attachment 1

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 26

Extended Power Uprate

Steam Dryer Analyses and Monitoring

Executive Summary

Total number of pages in Attachment 1 (excluding this cover sheet) is 10.

EXECUTIVE SUMMARY

Introduction and Purpose

This submittal provides Entergy's basis for concluding that Vermont Yankee Nuclear Power Station (VYNPS) steam dryer, as recently modified by Entergy, will perform its intended function at extended power uprate (EPU) conditions. Although the steam dryer performs a non-safety-related function, it must maintain its structural integrity to preclude the generation of loose parts that might impact a safety-related component.

Recent boiling water reactor (BWR) operating experience has shown that flow-induced fluctuating pressure loads can result in stresses of sufficient magnitude to cause a fatigue failure of the steam dryer. This submittal documents the methods used by Entergy to predict steam dryer fluctuating pressure loads and evaluate the capability of the VYNPS modified steam dryer to withstand those loads without generating loose parts. The pressure loading analysis relies, in part, on physical measurements made with pressure sensing equipment installed on the main steam system at VYNPS and an acoustic circuit model which converts those measurements into pressure loads on the steam dryer. In addition to the acoustic circuit model, Entergy also employed a diverse computational fluid dynamics (CFD) technique to evaluate the effects of vortex shedding on the steam dryer. The CFD evaluation provided results consistent with industry operating experience and actual VYNPS measurements under current operating conditions.

A benchmark test using a subscale model was conducted to demonstrate the ability of the acoustic circuit methodology to use measurements from the main steam system to predict steam dryer loads. The results of the benchmark test are presented in this submittal and confirm the adequacy of the acoustic circuit analysis to predict steam dryer loads.

The pressure sensing equipment installed on the VYNPS main steam system will be used during initial EPU power ascension to collect measurements for use in closely monitoring predicted steam dryer loads. The measurements will be compared to the fatigue stress endurance limit in order to assure that steam dryer loading remains below the limit and structural integrity is maintained. The power ascension test plan also calls for monitoring indications of steam dryer structural integrity, including the collection and measurement of main steam moisture carryover samples. The trending of other key plant parameters includes measuring main steam pressures and flow rates through individual steam lines.

Entergy will apply hold points at approximately every 5% power increase (i.e., a plateau) above currently licensed thermal power for engineering evaluations and conservative management decision-making during power ascension. These hold points will each be for a minimum of 168 hours.

Entergy has closely monitored industry operating experience and actively participated in industry efforts to evaluate and mitigate the effects of EPU loads on steam dryers. This submittal documents the basis for Entergy's conclusion that the current analytical model yields results that are consistent with industry experience at EPU conditions, in cases where severe steam dryer degradation either was or was not experienced. Additionally, comparisons between VYNPS and other facilities that have operated successfully at EPU conditions for an extensive

period are provided to document the basis for Entergy's conclusion that the expected performance of the VYNPS steam dryer is well bounded by operating experience.

Finally, Entergy commits to inspect the steam dryer during the next three refueling outages. The first opportunity for inspection would be during RFO-25, scheduled for the 4th quarter of 2005. Having sufficient run time at EPU prior to this outage would be invaluable in establishing VYNPS-specific operating experience. Assurance of steam dryer structural integrity during future operating cycles will be verified by the monitoring plan that is provided in a separate attachment to this submittal, and confirmed based on the refueling outage visual inspection, which would detect the onset of any flow induced vibration (FIV) fatigue indications.

In summary, Entergy believes that the analytical methods developed to predict and monitor pressure loads on the steam dryer, coupled with the detailed steam dryer monitoring plan and proposed license condition, assure that the steam dryer's structural integrity will be maintained at EPU conditions.

Background

Entergy previously submitted results of a VYNPS steam dryer analysis in support of EPU operation to the NRC in a letter dated July 2, 2004[1]. The NRC conducted a technical audit of the VYNPS steam dryer analysis at the GE Nuclear Energy San Jose engineering office on August 24 through 26, 2004. The NRC Staff concluded in its audit report (TAC No. MC0761) that the steam dryer analysis did not sufficiently demonstrate that the VYNPS steam dryer would be capable of maintaining its structural integrity under EPU conditions. Issues identified by the NRC staff included questions regarding the applicability and reasonableness of a generic load definition developed from previously instrumented steam dryers at BWRs other than VYNPS.

Entergy subsequently initiated plant-specific analyses in order to demonstrate that the VYNPS steam dryer structural integrity will be maintained at EPU conditions. This submittal describes the methodologies used in performing this updated VYNPS steam dryer structural integrity analysis. This is the second of two submittals which describe Entergy's integrated steam dryer analysis and monitoring approach. The previous submittal of December 9, 2004[2], which contained a proposed steam dryer power ascension test plan and license condition, is superseded by the steam dryer monitoring plan that is provided as a separate attachment to this letter.

NRC Audit and Resolution of NRC Staff Issues

The NRC staff performed an audit of the VYNPS steam dryer analysis on August 24 through August 26, 2004. As an outcome of the audit, the NRC staff expressed certain concerns with the GE generic steam dryer load definition and other issues. The NRC staff's audit is documented in an NRC audit report (TAC No. MC0761). Entergy has addressed each of the

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[1] Entergy letter to U.S. Nuclear Regulatory Commission, "Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263 – Supplement No. 8, Response to Request for Additional Information," BVY 04-058, July 2, 2004

[2] Entergy letter to U.S. Nuclear Regulatory Commission, "Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263 – Supplement No. 21, "Steam Dryer Power Ascension Testing," BVY 04-129, December 9, 2004

identified issues by, among other actions, developing a plant-specific load definition and applying it to the VYNPS steam dryer structural analysis. The specific issues raised by the NRC staff are listed below, along with Entergy's response.

NRC Issue #1:
The analysis has not adequately identified and verified the excitation sources for flow-induced vibration mechanisms that resulted in significant degradation of similar steam dryers at other boiling water reactor nuclear power plants operating at EPU conditions.

Entergy Response to Issue #1:
Theoretical excitation sources at VYNPS have been evaluated. Plant measurements have not shown that the identified potential VYNPS acoustic sources are excited at main steam velocities between 80% and 100% of currently licensed thermal power (CLTP). The VYNPS Steam Dryer Monitoring Plan (SDMP) will monitor vibration levels and detect the onset of source excitation before steam dryer degradation occurs. Other BWR licensees with steam dryers that have experienced significant structural integrity degradation are in the process of identifying plant-specific excitation sources in conjunction with their stream dryer analyses. These sources will subsequently be correlated to the identified fatigue failure mechanisms.

NRC Issue #2:
The analysis has not provided a complete load definition for the VY steam dryer for EPU conditions in light of several assumptions that have not been adequately justified.

Entergy Response to Issue #2:
The plant-specific VYNPS steam dryer load definition does not rely on the assumptions previously applied for extrapolating to EPU conditions. This analysis does not arrive at VYNPS EPU loads by extrapolation from current conditions. Rather, the analysis determines the CLTP load definition and establishes amplitude margins to the fatigue stress limit. The load definition during power ascension to EPU conditions will be evaluated to ensure that sufficient margin to the fatigue limit is maintained.

NRC Issue #3:
The analysis has not justified the applied methodology as realistic in light of assumptions to account for uncertainties that resulted in apparent significant overestimation of predicted steam dryer stresses.

Entergy Response to Issue #3:
The plant-specific VYNPS steam dryer load definition does not invoke the GE generic load definition, which required an adjustment factor in order to reflect that the VYNPS steam dryer is structurally intact at CLTP. The current analysis does not require the application of arithmetic adjustment factors, but relies on actual measured data for VYNPS.

NRC Issue #4:
The analysis might be non-conservative based on assumptions for reducing the stress experienced by steam dryer parts and the creation of new potential fatigue failure locations as a result of the modifications to the VY steam dryer.

Entergy Response to Issue #4:
As stated in the response to NRC Issue #3, the current analysis does not require the application of arithmetic factors to reduce calculated stress. The elimination of such factors

minimizes the potential for non-conservatism as a result of application of calculational factors. In addition, the structural analysis model is sufficiently rigorous to account for stress reallocation resulting from the VYNPS steam dryer strengthening modification.

NRC Issue #5:
The analysis has not validated the extrapolation of pressure peaks from original power levels to EPU conditions for the steam dryer at VY.

Entergy Response to Issue #5:
See Entergy's response to NRC Issue #2 above.

Analyses, Industry Experience and VYNPS Initiatives That Justify VYNPS Operation at EPU Conditions

1. Analyses

As further discussed below, this submittal documents the methods used by Entergy to predict steam dryer fluctuating pressure loads and demonstrate the ability of the VYNPS modified steam dryer to withstand those loads without generating loose parts.

2. Industry Experience

Measured, pre-EPU vibration levels in the VYNPS main steam system are lower than pre-EPU levels at the Quad Cities or Dresden units. Predicted VYNPS steam dryer pre-EPU stresses have substantial margin to the ASME fatigue limit and are also lower than those predicted for Quad Cities or Dresden at pre-EPU conditions.

Following lengthy periods of operation at EPU conditions, inspection of the Dresden units in October and November 2004 showed considerably less steam dryer damage than at Quad Cities. The Dresden steam dryer damage was manifested by weld cracking at both units, which was addressed by design modifications and repairs performed in 2004. The design change substantially improved the steam dryer outer hood structural capability. The modified Dresden steam dryers were evaluated and the determination made that structural integrity would be maintained at EPU conditions. Each of the Dresden units and Quad Cities Unit 2 now has a modification very similar to that installed proactively at VYNPS. Entergy has, proactively, strengthened the VYNPS steam dryer in a similar manner to the changes made at Dresden to significantly increase its structural capability for operation at EPU conditions.

No BWR operating experience at EPU conditions, other than Quad Cities, has shown an unacceptable steam dryer failure. Monticello, with a square hood steam dryer design similar to VYNPS, was granted a license amendment to operate with a 6.3% extended power uprate in 1998 (to a total uprate from original design of approximately 13.7%). Monticello has been operating with no evidence of steam dryer failure. An inspection of the Monticello steam dryer performed during the Spring 2005 outage resulted in identification of cracks similar to those found on the VYNPS steam dryer in 2004. Disposition of the Monticello cracks was "leave-as-is," as they were determined not to challenge the steam dryer's structural integrity.

3. Steam Dryer Monitoring Plan

Further justification for VYNPS' operation at EPU conditions is provided by Entergy's plan to monitor steam dryer performance during power ascension. Entergy developed a Steam Dryer Power Ascension Test Plan (SDPATP), submitted by letter dated December 9, 2004, which described a controlled and methodical approach for monitoring FIV loads in the VYNPS main steam system during initial EPU power ascension. The SDPATP has been further refined and is superseded by the SDMP described in Attachment 2 to this submittal. In addition to FIV loads, moisture carryover will be frequently measured to detect potential significant degradation in steam dryer structural integrity.

Entergy believes that this integrated approach, which relies on plant-specific analysis based on plant measurements, assessment and incorporation where appropriate of relevant industry experience, and a methodical verification strategy during power ascension, assures the ability to maintain steam dryer structural integrity at EPU conditions.

Summary of VYNPS Plant-Specific Steam Dryer Analysis Methodology

The VYNPS steam dryer analysis methodology was previously described in EPU license amendment request supplements dated January 31, 2004, July 2, 2004, September 23, 2004, October 7, 2004, and December 9, 2004[3]. This submittal describes Entergy's recent development and application of a plant-specific VYNPS steam dryer load definition. Information herein supersedes previously submitted load definition information. This submittal also describes the structural analysis method, which is similar to that performed previously with changes specified herein.

Entergy applied various methodologies for evaluating VYNPS steam dryer structural integrity to ensure that integrity is maintained at uprate conditions. For development of a VYNPS-specific steam dryer load definition, Entergy contracted with Continuum Dynamics Inc. (CDI) to apply an acoustic analysis using VYNPS main steam system measured fluctuating pressure data as input.

Additionally, Entergy contracted with Fluent, Inc. (Fluent) to develop a CFD model of the VYNPS steam dryer to corroborate the measured plant fluctuating pressure data.

The structural analysis of the VYNPS steam dryer was performed by GE using their 3-D finite element analysis with acoustic and CFD analysis output time histories as inputs. The finite element model is the same as that used for the previous VYNSP analysis of record.

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[3] Entergy letters to U.S. Nuclear Regulatory Commission regarding extended power uprate for the Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263, Supplements Nos. 5, 8, 15, 19, and 21

1. Acoustic Analysis

The CDI acoustic analysis methodology relies on measured plant main steam system fluctuating pressures to predict loads on the steam dryer. The CDI methodology, initially described in Entergy's October 7, 2004, submittal[4], uses a 3-dimensional Helmholtz solver to determine the propagation of acoustic pressure waves in the reactor vessel steam space and on to components of the steam dryer. The methodology defines the relationship between two measured pressure readings in each main steam line and projects that relationship through the vessel nozzle onto the steam dryer.

a. *Acoustic Analysis Methodology*

The CDI methodology is described in Entergy's submittal of October 7, 2004. Attachment 3 to this submittal contains a description of the CDI acoustic analysis report, "Methodology to Determine Unsteady Pressure Loadings on Components in Reactor Steam Domes," Revision 6, which has been updated to reflect damping and compliance in the transmitter instrument lines. CDI developed a three-dimensional acoustic circuit model of the VYNPS reactor vessel steam dome and steam dryer. The Helmholtz solution within the steam dome is coupled to a one-dimensional acoustic circuit solution in the main steam lines.

b. *Plant Data Collection and Processing*

VYNPS plant-specific main steam system data was used to develop the steam dryer load definition. To provide input to calculate the steam dryer FIV forcing function, VYNPS main steam system fluctuating pressure data from strain gages and pressure transmitters was measured and recorded at current licensed thermal power levels of 80%, 85%, 90%, 92%, 95%, 97% and 100%. These data consist of:

- Dynamic pressure measurements taken from pressure transducers installed on instrument lines from the four main steam line venture instrument racks. The venturi data were obtained from high speed pressure sensors installed on the venturi transmitter high pressure tap instrument line.

- Strain gages located on each of the four main steam lines between the reactor pressure vessel nozzles and the main steam safety relief valves (SRVs). This strain is related to the average pressure inside the piping. All the strain gages were oriented in the circumferential (hoop) direction.

- Synchronization of the strain gage measurements and the venturi pressure transducer measurements was achieved by recording the signal from one pressure transducer on the same data acquisition system as the strain gages.

Detailed information on the analysis of steam dryer differential pressure loads utilizing the acoustic load methodology is contained in Attachment 6.

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[4] Entergy letter to U.S. Nuclear Regulatory Commission, "Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263 – Supplement No. 20, Meeting on Steam Dryer Analysis," BVY 04-113, October 7, 2004

i. Strain Gage Sensitivity Evaluation

A test was conducted at Alden Research Labs to determine strain gage sensitivity using:

- an 18" Sch 80 A106 Gr B pipe (representative of the VYNPS main steam piping),
- a nominal 1000 psi pressure,
- the same strain gage configuration as used in the VYNPS steam line, and
- the VYNPS data acquisition system (used to acquire the plant data for the acoustic circuit analysis).

This test demonstrated that the strain can be measured as low as 0.02 μerms. The conversion of strain to pressure at full power temperature for the strain gages on the VYNPS steam lines is 3.906 psi/ με.

Assessing the lower bound sensitivity of the gages was limited by the A/D resolution for VYNPS data acquisition equipment 0.015με with a ±0.05V input limit and the noise floor introduced by the VYNPS Data Acquisition system. With VYNPS data acquisition system the noise floor is measured to be $0.02\mu e_{rms}$ for the 1-arm bridge and $0.010\mu e_{rms}$ for the 2-arm bridge using a transform size of 2048 samples and sample rate of 1024 samples per second. The VYNPS data collection for the acoustic analysis input was done with the one arm strain gage configuration. The acquisition system noise floor conservatively adds .008 P_{rms}^2 /Hz of energy to the strain gage acoustic model input data.

ii. Main Steam Piping Vibration Measurements

In addition to the strain gages, accelerometers used to measure main steam piping vibration during power ascension are installed close to the strain gages on main steam lines B and D. Although not used as input for the acoustic analysis, the piping vibration measurements provide confirmatory information on relative levels of main steam system flow induced vibration. Thirty-one (31) accelerometers were installed inside the drywell, twenty-one on the main steam piping. Of the twenty-one accelerometers installed on the main steam (MS) system, there are four accelerometers located near the strain gages, two on main steam line B and two on main steam line D.

The maximum RMS acceleration observed on all the accelerometers was 0.083 g_{rms} at 100% CLTP. Acceleration levels below 0.1 g_{rms} are considered to be very low. The accelerometers near the strain gages show good coherence with measured data. Overall the accelerometers and the strain gage data both show that VYNPS has very low acceleration levels.

c. <u>Acoustic Analysis Methodology Benchmark</u>

In order to evaluate the ability of CDI's acoustic circuit methodology to predict steam dryer loads, a "blind" benchmark test was performed using the GE Scale Model Test Facility (SMT) in San Jose, CA. This test involved taking pressure measurements from an instrumented main steam system and steam dryer on the BWR-3 SMT facility. CDI was

provided data from the eight points in the SMT steam piping, and one point on the exit plenum to the blower, as well as SMT flow and temperature information. All SMT steam dryer data from this test was held back in order to perform this benchmark assessment.

- CDI used the data provided as input to the acoustic circuit analysis to predict scale model steam dryer fluctuating pressures. These CDI-predicted steam dryer pressures were then compared to the actual scale model steam dryer measurements in this report. Therefore, the predictions of steam dryer loads were blind, since measured steam dryer loads were not provided prior to CDI's analysis.

The CDI methodology was benchmarked in the same manner as it was applied in the full-scale VYNPS steam dryer acoustic analysis; using eight measurements from the main steam system to predict steam dryer loads. The measurements are representative of the four strain gages and four pressure sensors installed in the VYNPS plant. The test cases were designed to assess how well the CDI acoustic model would predict acoustic pressures on the steam dryer when provided with the external piping measurements.

The benchmark results provide the justification and guidance for applying the CDI acoustic circuit methodology in predicting the full scale VYNPS steam dryer loads.

A detailed description of the Entergy's benchmark approach, test plan, results, and evaluation is provided in Attachment 4 'Acoustic Model Benchmark Dryer Acoustic Load Methodology.

d. VYNPS Theoretical Acoustic Frequencies

Entergy has calculated the theoretical source frequencies of potential acoustic sources in the VYNPS main steam system using standard acoustic principles and actual plant characteristics. These potential sources could cause an increase in resonant acoustic loads within the main steam system when the natural frequency of a source component is matched by the frequency of shear wave instability caused by flow across the discontinuity of the source. Acoustic sources of interest in the VYNPS main steam system include reactor core isolation cooling (RCIC) system and high pressure coolant injection (HPCI) system branch lines (long pipes) and spring safety valve (SSV) and safety relief valve (SRV) branch lines (short pipes connected to the MS lines).

Vortices generated from flow with a turbulent boundary layer over these main steam line cavities exhibit flow-dependent shedding frequencies. Unlike the resonator frequency, the shedding frequency will change at EPU conditions due to increased steam velocity. Vortex shedding frequencies have been calculated for cavities in the VYNPS main steam lines and are compared to the source harmonic resonance frequencies.

At CLTP, VYNPS measurements show no evidence of these acoustic sources in the main steam system, as evidenced by strain gage, pressure sensor or accelerometer data. Entergy will monitor for signs of source excitation during EPU power ascension testing.

e. Comparison to Dresden and Quad Cities

The VYNPS steam dryer acoustic circuit analysis fluctuating pressure loads are lower than those analyzed at Dresden and substantially lower than Quad Cities at pre-EPU conditions.

The low resolution VYNPS 100% CLTP results are compared to similar node locations at Dresden 2 for pre-EPU and EPU conditions in Figure 1. VYNPS peak loads are less than Dresden loads by approximately 25% for pre-EPU conditions. The peak Dresden steam dryer node maximum differential pressure increases from 0.4 psid at original license thermal power (OLTP) to slightly greater than 0.7 psid at EPU conditions.

Detailed information on the analysis of steam dryer differential pressure loads utilizing the acoustic load methodology is contained in Attachment 6.

2. Computational Fluid Dynamics Analysis

Entergy contracted with Fluent, Inc. to develop a CFD model of the VYNPS steam dryer, reactor pressure vessel (RPV) head/plenum and a partial model of the main steam lines. The model was used to run unsteady state large eddy simulation in order to confirm the presence of vortex shedding and calculate the magnitude of resulting steam dryer fluctuating pressure loads.

Entergy and Fluent developed a CFD model of the VYNPS steam dryer, reactor pressure vessel dome region, steam lines and steam chest. Specifically, the CFD calculation included performing a large-eddy simulation (LES) to isolate the effects of local vortex shedding on the steam dryer outer hood vertical plate and reinforcing gussets. Details of the CFD modeling and results are contained in Attachment 5 to this submittal.

3. Structural Analysis

As a result of BWR/3 steam dryer failures in the industry, Entergy has performed a comprehensive structural evaluation to demonstrate the adequacy of the VYNPS steam dryer integrity for EPU steam flow changes. The key issue has been the modeling of the FIV loading during normal operation.

The purpose of the analysis reported here is to update the FIV stresses using pressure fluctuating loads generated with the combination of an acoustic circuit model and a CFD LES model for vortex shedding. The acoustic circuit model, LES model and resulting alternating stresses result in a more realistic load definition and a basis for systematically monitoring changes to predicted steam dryer stresses during power ascension to EPU conditions.

The VYNPS acoustic circuit model was developed based on plant design/operation configuration and used VYNPS-specific measured pressure fluctuation data as input. The acoustic circuit methodology was benchmarked with scale model test results developed by GE for Entergy. The LES model characterizes the nature and magnitude of unsteady flow effects across the face of the dryer at the entrance to the main steam line nozzles. Each model generated time history pressure profiles that were input to the ANSYS finite element program to determine associated FIV stresses.

Maximum acoustic pressure stresses and vortex shedding stresses were extracted from separate finite element analyses. The stresses were conservatively combined and, where appropriate, multiplied by stress concentration factors that account for weld shape and size. The time history analyses was done with a +/-10% time step change to conservatively account for uncertainty in the frequency content of the FIV loads.

Significant enhancements made to the GE structural analysis methodology subsequent to previous Entergy EPU steam dryer submittals include:

1.) Dynamic steam dryer pressure time history loads generated by the CDI acoustic model were used as input.

2.) Time history loads from the acoustic analysis were applied in a three inch mesh in the dryer face region, in a six inch mesh in the inner bank region and in a twelve inch mesh for the inner most hoods.

3.) Time history loads from the CFD analysis were applied for a refined mesh on the dryer face region.

4.) Nominal stress intensity near the maximum stress intensity location was used in combination with a stress concentration factor to develop alternating stress.

5.) A time step of 1/1024 second (1024 Hz) was used to adequately represent loading up to 200 Hz.

The resulting maximum FIV stresses calculated for current power were about 25% of the 13,600 psi ASME fatigue endurance limit. In addition, normal, upset and faulted stresses were calculated and compared to the ASME Code allowable, with all conditions showing acceptable stresses.

Attachment 5 to this submittal provides the details of the structural analysis methodology and results.

Attachment 2

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 26

Extended Power Uprate

Steam Dryer Analyses and Monitoring

Steam Dryer Monitoring Plan

Total number of pages in Attachment 2 (excluding this cover sheet) is 8.

VERMONT YANKEE NUCLEAR POWER STATION
STEAM DRYER MONITORING PLAN[1]

Introduction and Purpose

This plan describes the course of action for monitoring and evaluating the performance of the Vermont Yankee Nuclear Power Station (VYNPS) steam dryer during power ascension testing and operation above 100% of the original licensed thermal power (OLTP), i.e., 1593 MWt, to the full 120% extended power uprate (EPU) condition of 1912 MWt to verify acceptable performance. Unacceptable steam dryer performance is a condition that could challenge steam dryer structural integrity and result in the generation of loose parts or cracks or tears in the steam dryer that result in excessive moisture carryover. During reactor power operation, performance is demonstrated through the measurement of a combination of plant parameters. The comparison of measured plant data against defined criteria, based on the steam dryer structural analysis of record, will provide predictive capabilities toward determining steam dryer structural integrity under EPU conditions.

The Steam Dryer Monitoring Plan (SDMP) is applicable during initial power ascension to 1912 MWt and continues after full EPU conditions until lack of structural flaws has been established to provide assurance of acceptable performance. A license condition for steam dryer monitoring is proposed to require operational surveillances as well as visual inspections of the steam dryer, which will be conducted during scheduled refueling outages.

Entergy will accept a license condition for VYNPS that is based on the SDMP.

Scope

The SDMP is primarily an initial power ascension test plan designed to assess steam dryer performance from 100% OLTP to 120% OLTP (i.e., 1912 MWt). Assuming that a license amendment authorizing EPU operations is issued during the current operating cycle, power ascension will be achieved in two steps:

- Step 1 will increase power from 100% to approximately 115% OLTP. VYNPS will not exceed 630 MWe gross during the current operating cycle (i.e., Cycle 24).

- Step 2 will increase power to 120% OLTP. This second step in power ascension will begin following the next refueling outage, currently scheduled for the 4th quarter of 2005.

- The SDMP applies to both Step 1 and Step 2. Elements of this plan will be implemented before EPU power ascension testing, and others may continue after power ascension testing.

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[1] This Steam Dryer Monitoring Plan replaces the Steam Dryer Power Ascension Test Plan and Proposed License Condition that was proposed in Entergy's letter of December 9, 2004, "Vermont Yankee Nuclear Power Station, Technical Specification Proposed Change No. 263 – Supplement No. 21, Extended Power Uprate – Steam Dryer Power Ascension Testing," BVY 04-129

If a license amendment is not granted before the next refueling outage, the power uprate will be accomplished in a single step, and the SDMP will be carried out throughout the power ascension process.

Operating Specifications

When initially operating at a power level above 1593 MWt, the parameters identified in Table 1 – which are indicative of steam dryer integrity – shall be monitored at the frequencies specified and shall meet applicable performance criteria specified in Table 2. The surveillance requirements of Table 1 will be effective during power ascension to any power level that was not previously attained. Any change to the performance criteria, required actions, or surveillance requirements in Tables 1 or 2 can only be made in accordance with the proposed steam dryer license condition (see Table 3).

Initial EPU power ascension testing above 100% OLTP will be conducted in 2.5% OLTP steps and 5% OLTP plateaus. The initial power ascension will include a 4-hour hold at each 2.5% step and a minimum 168-hour hold at each 5% plateau.

Table 2 establishes the criteria for verifying acceptable steam dryer performance based on moisture carryover and main steam line pressure data. If the Level 1 or Level 2 performance criteria are exceeded, the actions and completion times specified shall be met for the given condition. Reactor power operation that results in moisture carryover and steam pressures that are less than the Level 2 performance criteria in Table 2 is representative of fully acceptable steam dryer performance.

Additionally, if the performance criteria in Table 2 are exceeded, the following actions will be taken depending upon the criteria exceeded:

1. Either suspend reactor power ascension or reduce reactor power, initiate a Condition Report, and evaluate the cause of any exceedance of the performance criteria.

2. Prior to increasing reactor thermal power to a level higher than any previously attained, the plant conditions relevant to steam dryer integrity and associated evaluation results shall be reviewed by the on-site safety review committee, and a recommendation shall be made to the General Manager, Plant Operations prior to increasing power for each 5% power plateau.

3. Strain gage pressure and moisture carryover data collected at each 5% power plateau will be made available to the NRC through its resident inspector.

4. Each initial increase in reactor thermal power to the next higher 5% power plateau above 100% OLTP must be authorized by the General Manager, Plant Operations.

Table 1
Steam Dryer Surveillance Requirements During Reactor Power Operation Above a Previously Attained Power Level

Parameter	Surveillance Frequency
1. Moisture Carryover	Every 24 hours (Notes 1 and 2)
2. Main steam line pressure data from strain gauges	Hourly when initially increasing power above a previously attained power level. AND At least once at every 2.5% (nominal) power step above 100% OLTP. (Note 3)
3. Main steam line pressure data from pressure transducers	At least once at every 2.5% (nominal) power step above 100% OLTP. (Note 3) AND Within one hour after achieving every 2.5% (nominal) power step above 100% OLTP.

Notes to Table 1:

1. If a determination of moisture carryover cannot be made within 24 hours of achieving a 5% power plateau, an orderly power reduction shall made within the subsequent 12 hours to a power level at which moisture carryover was previously determined to be acceptable. For testing purposes, a power ascension step is defined as each power increment of 2.5% (nominal) over OLTP, i.e., at thermal power levels of approximately 102.5%, 105%, 107.5%, 110%, 112.5%, 115%, 117.5%, and 120% OLTP. Power level plateaus are nominally every 5% of OLTP greater than 100% (i.e., approximately 80 MWt).

2. Provided that the Level 2 performance criteria in Table 2 are not exceeded, when steady state operation at a given power exceeds 168 consecutive hours, moisture carryover monitoring frequency may be reduced to once per week.

3. The strain gage surveillance shall be performed hourly when increasing power above a level at which data was previously obtained. The surveillance of both the strain gage data and main steam line pressure data is also required to be performed once at each 2.5% power step above 100% OLTP and within one hour of achieving each 2.5% step in power, i.e., at thermal power levels of approximately 102.5%, 105%, 107.5%, 110%, 112.5%, 115%, 117.5%, and 120% OLTP. If the surveillance is met at a given power level,

additional surveillances do not need to be performed at that power level where data had previously been obtained.

If valid strain data cannot be recorded hourly or within one hour of initially reaching a 2.5% power step from at least three of the four main steam lines, an orderly power reduction shall be made to a lower power level at which data had previously been obtained. Any such power level reduction shall be completed within the two hours of determining that valid data was not recorded.

Table 2
Steam Dryer Performance Criteria and Required Actions

Performance Criteria Not to be Exceeded	Required Actions if Performance Criteria Exceeded and Required Completion Times
Level 2: • Moisture carryover exceeds 0.1% OR • If an engineering evaluation concludes that moisture carryover > 0.1% is acceptable: Moisture carryover exceeds 0.1% and increases by > 50% over the average of the three previous measurements taken at > 1593 MWt OR • Pressure data exceed Level 2 Spectra[1]	1. Promptly suspend reactor power ascension until an engineering evaluation concludes that further power ascension is justified. 2. Before resuming reactor power ascension, the steam dryer performance data shall be reviewed as part of an engineering evaluation to assess whether further power ascension can be made without exceeding the Level 1 criteria.
Level 1: • Moisture carryover exceeds 0.35% OR • Pressure data exceed Level 1 Spectra[1]	1. Promptly initiate a reactor power reduction and achieve a previously acceptable power level (i.e., reduce power to a previous step level) within two hours, unless an engineering evaluation concludes that continued power operation or power ascension is acceptable. 2. Within 24 hours, re-measure moisture carryover and perform an engineering evaluation of steam dryer structural integrity. If the results of the evaluation of steam dryer structural integrity do not support continued plant operation, the reactor shall be placed in a hot shutdown condition within the following 24 hours. If the results of the engineering evaluation support continued power operation, implement steps 3 and 4 below. 3. If the results of the engineering evaluation support continued power operation, reduce further power ascension step and plateau levels to nominal increases of 1.25% and 2.5% of 1912 MWt, respectively, for any additional power ascension. 4. Within 30 days, the transient pressure data shall be used to calculate the steam dryer fatigue usage to demonstrate that continued power operation is acceptable.

[1] The EPU spectra shall be determined and documented in an engineering calculation or report. Acceptable Level 2 spectra shall be based on maintaining $\leq$ 80% of the ASME allowable alternating stress (S_a) value at 10^{11} cycles (i.e., 10.88 ksi). Acceptable Level 1 Spectra shall be based on maintaining the ASME S_a at 10^{11} cycles (i.e., 13.6 ksi).

Data Collection

During initial EPU power ascension, plant data will be measured and recorded, as a minimum, at power steps corresponding to approximately 102.5%, 105%, 107.5%, 110%, 112.5%, 115%, 117.5%, and 120% OLTP. In addition, Entergy will monitor pressure data from the main steam strain gauges hourly during initial power ascension. The plant will be held at each 5% power plateau for a minimum of 168 hours to allow sufficient time to evaluate test results. Depending upon actual performance, smaller power increase increments may be used. Data collected will consist of:

- Dynamic pressure measurements taken from four pressure transducers installed on transmitters associated with each main steam line venturi.

- Measurements taken from strain gauges located on each of the four main steam lines between the reactor pressure vessel nozzles and the closest inboard safety/safety relief valve.

- Moisture carryover measurements will be made during power ascension testing above 100% OLTP in accordance with SIL 644[1].

- Plant data that may be indicative of off-normal steam dryer performance will be monitored during power ascension (e.g., level, steam flow, feed flow, etc.). Plant data can provide an early indication of unacceptable steam dryer performance.

Evaluations

Data collected at each power ascension step will be evaluated relative to the performance criteria.

In addition, other reactor operational parameters that may be influenced by steam dryer integrity (e.g., steam flow distribution between the individual steam lines) should be monitored with the intent of detecting structural degradation of the steam dryer during plant operation (e.g., flow distribution between individual main steam lines). The enhanced monitoring of selected plant parameters will be controlled by plant procedures.

If any of the performance criteria in Table 2 are exceeded, the plant conditions relevant to steam dryer integrity and the associated evaluation results shall be reviewed by the on-site safety review committee at every 5% power plateau and prior to increasing power. Permission to ascend in power will be granted by the General Manager, Plant Operations.

Reporting to NRC

1. Steam Dryer Visual Inspections: The results of the visual inspections of the steam dryer conducted during the next three refueling outages (beginning with

[1] GE Nuclear Energy, Services Information Letter, SIL No. 644, Revision 1, "BWR Steam Dryer Integrity," November 9, 2004

the 2005 refueling outage) shall be reported to the NRC staff within 60 days following startup from the respective refueling outage.

2. SDMP: The results of the SDMP shall be submitted to the NRC staff in a report within 60 days following the completion of all EPU power ascension testing. Contemporary data and results from steam dryer monitoring will be available on-site for review by NRC inspectors as it becomes available. The written report on steam dryer performance during EPU power ascension testing will include evaluations or corrective actions that were required to obtain satisfactory steam dryer performance. The report will include relevant data collected at each power step, comparisons to performance criteria (design predictions), and evaluations performed in conjunction with steam dryer integrity monitoring.

3. During initial power ascension testing, steam dryer performance data will be made available to the NRC through its resident inspector at each 5% power plateau.

Long Term Actions

The VYNPS steam dryer will be inspected during the refueling outages scheduled for the Fall 2005, Spring 2007, and Fall 2008. The inspection will be comparable to the inspection conducted during the Spring 2004 refueling outage.

Following completion of power ascension testing, moisture carryover measurements will continue to be made periodically in accordance with GE SIL 644 and plant procedures.

Equipment associated with temporarily installed pressure monitoring sensors and strain gauges may be removed from service following the achievement of one full operating cycle after issuance of the EPU license amendment and satisfaction of the license condition requiring steam dryer inspection.

Table 3
PROPOSED STEAM DRYER LICENSE CONDITION

1. When operating above 1593 MWt (i.e., at power uprate conditions), the operating limits, required actions, and surveillances specified in the Steam Dryer Monitoring Plan (SDMP) shall be met. The following key attributes of the SDMP shall not be made less restrictive without prior NRC approval:

   a. During initial power ascension testing above 1593 MWt, each test plateau increment shall be approximately 80 MWt; and

   b. Level 1 performance criteria; and

   c. The methodology for establishing the stress spectra used for the Level 1 and Level 2 performance criteria.

   Changes to other aspects of the SDMP may be made in accordance with the guidance of NEI 99-04[2].

2. During each of the next three refueling outages (beginning with the 2005 refueling outage), a visual inspection shall be conducted of all accessible, susceptible locations of the steam dryer, including flaws left "as-is" and modifications.

3. The results of the visual inspections of the steam dryer conducted during the next three refueling outages (beginning with the 2005 refueling outage) shall be reported to the NRC staff within 60 days following startup from the respective refueling outage. The results of the SDMP shall be submitted to the NRC staff in a report within 60 days following the completion of all extended power uprate power ascension testing.

4. The requirements of Item 1 above shall be implemented upon issuance of the EPU license amendment and shall continue until the completion of one full operating cycle at EPU. If an unacceptable structural flaw (due to fatigue) is detected during the subsequent visual inspection of the steam dryer, the requirements of Item 1 above shall extend another full operating cycle. The requirements of Item 1 will remain in effect until a visual inspection standard of no new, unacceptable flaws/flaw growth based on visual inspection is satisfied by the steam dryer.

5. This license condition shall expire upon satisfaction of Items 2, 3 and 4 above.

[2] Nuclear Energy Institute, "Guidelines for Managing NRC Commitment Changes," NEI 99-04, Revision 0, July 1999

Attachment 4

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 26

Extended Power Uprate

Steam Dryer Analyses and Monitoring

VY-RPT-05-00006 VYNPS Acoustic Model Benchmark- Dryer Acoustic Load Methodology

Attachment 4 will be provided under separate cover.

Attachment 8

Vermont Yankee Nuclear Power Station

Proposed Technical Specification Change No. 263 – Supplement No. 26

Extended Power Uprate

Steam Dryer Analyses and Monitoring

Affidavit (Continuum Dynamics, Inc.)

Total number of pages in Attachment 8 (excluding this cover sheet) is 2.

Continuum Dynamics, Inc.
(609) 538-0444 : (609) 538-0464 fax 34 Lexington Avenue Ewing, NJ 08618-2302

AFFIDAVIT

Re: "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," C.D.I. Report No. 04-09P Rev. 6, prepared by Continuum Dynamics, Inc., dated March 2005.

I, Alan J. Bilanin, being duly sworn, depose and state as follows:

1. I hold the position of President and Senior Associate of Continuum Dynamics, Inc. (hereinafter referred to as C.D.I.), and I am authorized to make the request for withholding from Public Record the Information contained in the documents described in Paragraph 2. This Affidavit is submitted to the Nuclear Regulatory Commission (NRC) pursuant to 10 CFR 2.390(a)(4) based on the fact that the attached information consists of trade secret(s) of C.D.I. and that the NRC will receive the information from C.D.I. under privilege and in confidence.

2. The Information sought to be withheld, as transmitted to Entergy Vermont Yankee as attachments to C.D.I. Letter No. 05058 dated 30 March 2005, C.D.I. Report No. 04-09P, Rev. 6, entitled "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," prepared by Continuum Dynamics, Inc., dated March 2005.

3. The Information summarizes:

   (a) a process or method, including supporting data and analysis, where prevention of its use by C.D.I.'s competitors without license from C.D.I. constitutes a competitive advantage over other companies;
   (b) Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;
   (c) Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

   The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs 3(a), 3(b) and 3(c) above.

4. The Information has been held in confidence by C.D.I., its owner. The information has consistently been held in confidence by C.D.I. and no public

disclosure has been made and it is not available to the public. All disclosures to third parties, which have been limited, have been made pursuant to the terms and conditions contained in C.D.I.'s Nondisclosure Secrecy Agreement which must be fully executed prior to disclosure.

5. The Information is a type customarily held in confidence by C.D.I. and there is a rational basis therefore. The Information is a type, which C.D.I. considers trade secret and is held in confidence by C.D.I. because it constitutes a source of competitive advantage in the competition and performance of such work in the industry. Public disclosure of the Information is likely to cause substantial harm to C.D.I.'s competitive position and foreclose or reduce the availability of profit-making opportunities.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to be the best of my knowledge, information and belief.

Executed on this 30 day of March 2005.

Alan J. Bilanin
Continuum Dynamics, Inc.

Subscribed and sworn before me this day: 30 March 2005

Barbara A. Agans, Notary Public

BARBARA A. AGANS
NOTARY PUBLIC OF NEW JERSEY
MY COMM. EXPIRES MAY 6, 2007