Attachment 15

Peach Bottom Atomic Power Station Units 2 and 3

NRC Docket Nos. 50-277 and 50-278

Replacement Steam Dryer Evaluation for Peach Bottom Atomic Power Station Units 2 and 3 (Non-Proprietary)

Westinghouse Non-Proprietary Class 3

WCAP-17635-NP - Enclosure 15A
Revision 1

September 2012

Peach Bottom Atomic Power Station Unit 2 and Unit 3 Replacement Steam Dryer Comprehensive Vibration Assessment Program (CVAP)

WCAP-17635-NP – Enclosure 15A
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Peach Bottom Atomic Power Station Unit 2 and Unit 3 Replacement Steam Dryer Comprehensive Vibration Assessment Program (CVAP)

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September 2012

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ACRONYMS AND ABBREVIATIONS

ACM	Acoustic Circuit Model
BWR	Boiling Water Reactor
CLTP	Current Licensed Thermal Power
CVAP	Comprehensive Vibration Assessment Program
DAS	Data Acquisition System
EPU	Extended Power Uprate
FIV	Flow Induced Vibration
FEM	Finite Element Model
GDC	General Design Criteria
LAR	License Amendment Request
MCO	Moisture Carryover
MSL	Main Steam Line
NRC	Nuclear Regulatory Commission
OD	Outside Diameter
OE	Operating Experience
OEM	Original Equipment Manufacturer
OLTP	Original Licensed Thermal Power
PBAPS	Peach Bottom Atomic Power Station
RG	Regulatory Guide
RPV	Reactor Pressure Vessel
RSD	Replacement Steam Dryer
SAFDL	Specified Acceptable Fuel Design Limits
SG	Strain Gauge
SRP	Standard Review Plan
SRV	Safety Relief Valve
SSC	Systems, Structures, and Components

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1 OVERVIEW

Exelon Nuclear is in the process of submitting extended power uprate (EPU) applications for the Peach Bottom Atomic Power Station (PBAPS) Unit 2 and PBAPS Unit 3 plants. As part of the EPU License Amendment Request (LAR), Exelon is proposing to replace the existing Original Equipment Manufacturer (OEM) parallel panel steam dryers with a Westinghouse 3-ring octagonal steam dryer (RSD).

The purpose of this document is to describe the Comprehensive Vibration Assessment Program (CVAP) for the replacement steam dryers for these plants and to demonstrate the acceptability of the program to the applicable U.S. Nuclear Regulatory Commission (NRC) regulatory requirements and guidance. As such, this document provides an overview of the site-specific analysis, measurement and inspection programs documented in Enclosures B.1 through B.7 of this attachment that verify the structural integrity of the PBAPS Units 2 and 3 replacement steam dryers.

Section 2 of this report provides an overview of the replacement steam dryer design and analysis techniques as well as a summary description of the CVAP and the classification strategy for the prototype and non-prototype plants. Section 3 identifies additional enclosures to this attachment that provide: (1) a summary of the analysis methods and results for determining acoustic loads and acoustic stresses on the dryer, (2) a description of the subscale testing used for deriving scaling spectra from current licensed thermal power (CLTP) with the OEM dryer to EPU conditions with the RSD, and (3) analysis description and results for the ASME stress report. Section 4 describes the instrumentation to be provided on the PBAPS Unit 2 prototype plant and on the PBAPS Unit 3 non-prototype plant that will provide the data used for determination of the stresses on the RSD and to verify the predictive analysis is adequate to confirm the calculation of those stresses. Section 5 provides the RSD inspection plan description for both the prototype and non-prototype plant dryers. Section 6 identifies the LAR enclosure for the power ascension test program. Section 7 provides a summary of the content and schedule for NRC reports. Section 8 provides a list of references.

1.1 REGULATORY BASIS AND GUIDANCE

Reactor internals components, including the steam dryer, must be designed to meet the requirements of the applicable NRC General Design Criteria (GDC), commensurate with their safety function. Although some internals components, such as the steam dryers, perform no safety function, they must retain their structural integrity to avoid generation of loose parts that may adversely impact the capability of other systems, structures, and components (SSCs) to perform their safety function. The NRC's acceptance criteria for EPU conditions per the guidance of RS-001, "Review Standard for Extended Power Uprates," are based on 10 CFR 50.55a and the following GDC's.

- 10 CFR 50.55a and GDC-1 require that SSCs important to safety be designed, fabricated, erected, constructed, tested, and inspected to quality standards commensurate with the importance of the safety functions to be performed, and address adverse flow effects.

- GDC-2 requires that SSCs important to safety be designed to withstand the effects of earthquakes combined with the effects of normal or accident conditions.

- GDC-4 requires that SSCs important to safety be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, and includes acoustic vibration loads, operational transients, and postulated pipe rupture transient.

- GDC-10 requires that the reactor core be designed with appropriate margin to assure that specified acceptable fuel design limits (SAFDLs) are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. There must be no adverse impact on fuel, reactivity control, or core cooling.

Specific guidance for meeting these regulations is provided in Standard Review Plan (SRP) 3.9.1, "Special Topics for Mechanical Components," SRP 3.9.2, "Dynamic Testing and Analysis of Systems, Structures, and Components," SRP 3.9.3, "ASME Code Class 1, 2, and 3 Components and Component Supports, and Core Support Structures," and SRP 3.9.5, "Reactor Pressure Vessel Internals." The SRPs (SRP 3.9.2 and SRP 3.9.5) reference Regulatory Guide (RG) 1.20 and emphasize vibration prediction through analysis and measurement programs, monitoring of plant data and inspection programs to verify no adverse flow effects during power ascension and long-term power operation.

Exelon has defined a program that will demonstrate the integrity of the steam dryers is maintained during EPU power ascension and EPU power operation consistent with the requirements of the GDCs. This document describes the predictive analysis, measurement program, and inspection program to verify the structural integrity of the steam dryer for flow-induced vibrations. It also describes how the guidance of RG 1.20 is applied for PBAPS Unit 2 and PBAPS Unit 3 replacement steam dryers. Included in Section 2.2 is identification of PBAPS Unit 2 as the prototype plant and PBAPS Unit 3 as a non-prototype Category I plant as well as the basis for these classifications consistent with the guidance of RG 1.20.

2 BACKGROUND, DESIGN OVERVIEW, AND CVAP

This section provides an overview of the replacement steam dryer design and analysis techniques as well as a summary description of the CVAP and the classification strategy for the prototype and non-prototype plants.

2.1 DESIGN OF THE REPLACEMENT STEAM DRYER

For the Exelon EPU Replacement Steam Dryer project, a robust design for the PBAPS Unit 2 and PBAPS Unit 3 plants was developed with panels arranged in a concentric polygon shape. The general layout of this dryer is shown in Figure 2-1.

Figure 2-1 Westinghouse Replacement Steam Dryer Configuration
(Figure 2-1 is representative of the PBAPS Unit 2 Dryer with instrumentation mast (5) and hold down rods (6))

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2.1.1 Modeling Techniques for Design

2.1.1.1 Load Definition Modeling

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2.1.1.2 Structural Evaluation Modeling

The process used to perform the steam dryer structural analysis involves multiple acoustic and structural analyses, scale model testing, and several computer codes, both commercially available and special-purpose codes developed in conjunction with the evaluation of acoustic loads.

The extent of the acoustic qualification of the dryer is to assess the potential for high-cycle fatigue (Enclosure B.2 of this attachment). Structural qualification of the replacement dryer for the remaining duty cycle of events applicable to the operating system of the applicable plants is documented in the ASME Code Stress Report (Enclosure B.3 of this attachment).

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2.1.2 Material

The steam dryer is fabricated of stainless steel plates, bars, and forgings. The physical properties are listed in the ASME Code Stress Report (Enclosure B.3 of this attachment).

2.1.3 Treatment of Structural Damping

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2.2 COMPREHENSIVE VIBRATION ASSESSMENT PROGRAM (CVAP)

This section provides a summary description of the CVAP for the PBAPS Unit 2 and PBAPS Unit 3 plant RSD programs at EPU conditions. It also describes the basis for the categorization of PBAPS Unit 2 as the prototype and for PBAPS Unit 3 as non-prototype Category I as defined in Regulatory Guide 1.20, Revision 3.

2.2.1 Summary Description

The CVAP for the RSD at EPU conditions for PBAPS Unit 2 and PBAPS Unit 3 plants, consistent with Regulatory Guide 1.20, includes a vibration and fatigue analysis, a vibration measurement program, an inspection program, and a correlation of their results. Details of the analysis are discussed in Section 3, the vibration measurement programs are described in Section 4, and the inspection programs are described in Section 5.

The structural analysis for the steam dryer consists of two components: (1) the acoustic loads on the dryer generated as a result of dynamic steam flow effects in the MSLs, and (2) the non-acoustic loads such as deadweight, differential pressure, and seismic.

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The CVAP Inspection Plan for the prototype PBAPS Unit 2 plant, consistent with Section 2.3 of Regulatory Guide 1.20, involves an inspection of the steam dryer for any evidence of damage due to flow-induced vibration following a full cycle of plant operation. The inspection is scheduled for the first refueling outage following the installation of the dryer and operation at EPU conditions, consistent with References 1 and 2 (See Section 5). The results of inspections at similar plants using a similar dryer design have been factored into the determination of inspection locations on this dryer. The Unit 3 dryer inspection is consistent with section 3.1.3 of Regulatory Guide 1.20. The inspections of the non-prototype

dryer will incorporate any lessons learned as a result of the inspection on the prototype dryer. Additional details of the inspection plans are discussed in Section 5.

2.2.2 Classification

This section provides a basis for the classification of PBAPS Unit 2 as the prototype plant and PBAPS Unit 3 as non-prototype Category I plant.

The PBAPS Unit 2 prototype RSD is planned to be installed during a scheduled refueling outage in September 2014 and the EPU power ascension program for that RSD will be conducted following that outage. A report will be submitted to the NRC, as described in Section 7, which documents the correlation of the predicted acoustic loads on the RSD with the RSD stress measured by the instrumentation on the RSD.

The PBAPS Unit 3 non-prototype RSD is planned to be installed during a scheduled refueling outage in September 2015 and the EPU power ascension program for that RSD will be conducted following that outage.

During the next scheduled Unit 2 refueling outage following EPU operation in September 2016, the Unit 2 prototype RSD will be inspected to further confirm the measured RSD performance during EPU operation. The results of the prototype RSD inspection will be included as part of the Preliminary Report described in Section 7.

The sequencing described above in 2014 through 2016 is acceptable for designating the PBAPS Unit 3 RSD as non-prototype category I because:

- The PBAPS Unit 3 RSD is substantially the same as the PBAPS Unit 2 RSD. Any nominal dryer and reactor pressure vessel differences are accounted for in the subscale testing results, the load definitions from the ACM, the structural analysis, the power ascension programs, and the power ascension limit curves.

- Measurements from the Unit 2 prototype RSD instrumentation will have validated that the ACM 4.1 methodology that will be applied during Unit 3 power ascension vibration measurement program provides an adequate prediction of the stresses due to EPU operating loads on the RSD.

- Execution of the power ascension plan (and associated limit curves) for the PBAPS Unit 3 non-prototype RSD will ensure sufficient margin to ASME Code stress limits is maintained during full EPU operating conditions.

- This approach meets the underlying regulatory requirements of Regulatory Guide 1.20 set forth in the GDCs and SRPs by: (1) having verified no adverse flow effects during power ascension and had not experienced any adverse in-service vibration phenomena during EPU operation, (2) having demonstrated the ability to predict dryer acoustic responses via an analysis and measurement program, (3) having a start up testing and monitoring program, and (4) having an acceptable inspection program.

2.2.2.1 Prototype (Peach Bottom Unit 2)

The first Westinghouse RSD is to be installed on the PBAPS Unit 2 plant, which is designated as a prototype plant. A prototype, consistent with RG 1.20, Section 1.1, is a configuration that represents a first of a kind or unique design. The PBAPS Unit 2 plant, operating at EPU power level conditions and using the Westinghouse RSD design represents, as of the date of this application, such a first of a kind configuration.

The PBAPS Unit 2 CVAP, as described in this report and in the reference documents herein, is consistent with the guidance contained in RG 1.20 for an acceptable CVAP for reactor internals for a prototype plant. This includes analysis, measurement and inspection programs as well as a correlation and evaluation of results.

2.2.2.2 Non-Prototype Category I

This subsection describes the basis for the non-prototype Category I classification for the PBAPS Unit 3 RSD.

2.2.2.2.1 Regulatory Guide 1.20

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2.2.2.2.2 Comparison of Plant Differences

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Table 2-1 Comparison of Key Steam Dryer Parameters

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Table 2-2 Comparison of Key Reactor Pressure Vessel Parameters

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Table 2-3 Comparison of Key Hydraulic Parameters

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Table 2-4 Comparison of Key Main Steam Line Parameters

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Table 2-4 Comparison of Key Main Steam Line Parameters (cont'd)

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3 ANALYSIS OF THE REPLACEMENT STEAM DRYER

3.1 ACOUSTIC CIRCUIT MODEL

Qualifying the Westinghouse steam dryer design for acoustic pressure loads originating from flow-induced vibration phenomena requires defining the effects of acoustic pressure loads on the structure. The details of how these loads are calculated, including a description of the acoustic pressure wave model, acoustic load definition development, and development of an EPU acoustic load definition are provided in the Acoustic Load Definition Report (Enclosure B.1 of this attachment).

3.2 SCALE MODEL TESTING OF THE REPLACEMENT STEAM DRYER

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3.3 STRESS ANALYSIS OF THE REPLACEMENT STEAM DRYER

An overview of the stress evaluation is provided in Subsection 2.1.1.2. The objective of that analysis is to show that the maximum alternating stress intensity anywhere in the dryer is less than the material endurance strength. A minimum stress ratio greater than 2.0 is demonstrated for acoustic loads. Enclosures B.1 and B.2 of this attachment provide a detailed description of load application, structural analysis, and analysis results for acoustic stresses.

The replacement steam dryer is analyzed according to the guidelines in the [ ]b,c. Enclosure B.3 of this attachment provides the analysis description and results for the stresses resulting from the loads due to deadweight, earthquake, and differential pressure, which are in turn combined with the acoustic stresses as described in that enclosure to determine the total stress on the dryer.

4 MEASUREMENT PROGRAM OVERVIEW

This section describes the direct dryer instrumentation to be provided on the PBAPS Unit 2 prototype plant. It also describes the main steam line instrumentation that will provide the data used for determination of the stresses on the RSD and to ensure the predictive analysis adequately confirms the calculation of those stresses for both PBAPS Unit 2 and Unit 3.

4.1 INSTRUMENTATION PROVIDED WITH THE REPLACEMENT STEAM DRYER (PBAPS UNIT 2, PROTOTYPE)

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4.2 INSTRUMENTATION ON THE MAIN STEAM LINES (PBAPS UNIT 2 AND PBAPS UNIT 3)

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5 INSPECTION PROGRAM OVERVIEW

5.1 INSPECTION PLAN DESCRIPTION

This section provides the RSD inspection plan description for both the prototype and non-prototype plant dryers.

5.2 INTERGRANULAR STRESS CORROSION CRACKING (IGSCC) AND HIGH CYCLE FATIGUE CRACKING CONSIDERATIONS

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5.3 PRE-INSTALLATION INSPECTIONS

Consistent with BWRVIP-181-A recommendations, a pre-installation inspection will be performed to confirm dimensional tolerances for all replacement steam dryers. Surface roughness and weld finish will also be confirmed to be consistent with BWRVIP-181-A. Subsequent dryer inspections can be compared to the results of the pre-service inspection.

5.4 PROTOTYPE PLANT DRYER INSPECTION PLAN FOLLOWING FIRST CYCLE OF OPERATION

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Table 5-1 Inspection Locations for Prototype Plant Following 1st Cycle of Operation at EPU Conditions

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Figure 5-1 View of Outer Hood


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Figure 5-2 Top View of RSD

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Figure 5-3 Bottom View of RSD

5.5 NON-PROTOTYPE PLANT DRYER INSPECTION PLAN FOLLOWING FIRST CYCLE OF OPERATION

The non-prototype RSD will be inspected at the first refueling outage following dryer installation and operation at EPU conditions. Inspection plans will be incorporated into the PBAPS Unit 3 steam dryer inspection programs that reflect the results from the Unit 2 Inspections. The inspection locations are shown in Table 5-2. The dryer inspection locations for the PBAPS Unit 3 Non-Prototype are the same as the PBAPS Unit 2 Prototype with the exception of locations under the dryer. Locations under the dryer are not included for Unit 3 because the results of the Unit 2 dryer inspection are expected to be adequate to confirm no flaws with the under dryer inspection locations and there is no difference between the Unit 2 and Unit 3 dryers. However, these inspection plans will be "living documents," which will be modified as appropriate to incorporate lessons learned from other dryer inspections, such as those at Monticello and PBAPS Unit 2.

Table 5-2 Inspection Locations for Non-Prototype Plant Following 1st Cycle of Operation at EPU Conditions

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5.6 INSPECTIONS SUBSEQUENT TO THE FIRST OPERATING CYCLE INSPECTION

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Table 5-3 Inspection Locations for Both Plants Subsequent to the First Operating Cycle Inspection

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6 POWER ASCENSION PROGRAM OVERVIEW

The power ascension test program is divided into two parts to facilitate testing: from startup to 100% of CLTP conditions and from 100% CLTP to EPU conditions. The details of the test including the data acquisition system, instrument description, procedure for data collection, comparison of data with design data, and actions to be taken if acceptance criteria are not met are provided in the Replacement Steam Dryer Power Ascension Program Description for Extended Power Uprate Report (Enclosure B.4 of this attachment).

7 NRC WRITTEN REPORTS

Exelon will provide written reports following completion of power ascension testing and inspections consistent with the guidance contained in RG 1.20 Rev 3. The reports will include relevant data collected at each power step, comparisons to performance criteria (design predictions), and evaluations performed in conjunction with steam dryer structural integrity monitoring.

The reports to be provided are as follows:

1. Evaluation Summary Report – This report will be consistent with the guidance contained in RG 1.20 Rev 3, section C.2.2(2)(a) and provide a summary evaluation of plant startup and power ascension to EPU power levels. This report will be submitted to the NRC staff within 90 days of reaching EPU power levels. This report will provide the results of both the direct and indirect dryer monitoring and comparison against the predicted using the ACM methodology.

2. Preliminary Report – The preliminary report will be consistent with the guidance contained in RG 1.20 Rev 3, section C.2.4(1) which states: "The preliminary report should summarize an evaluation of the raw and, as necessary, limited processed data and the results of the inspection program with respect to the test acceptance criteria. Anomalous data that could bear on the structural integrity of the reactor internals should be identified, as should the method to be used for evaluating such data." This report will provide inspection results and will be provided to the NRC within 60 days following completion of the first inspection in accordance with RG 1.20 Rev 3, section C.2.5(5).

3. Final Report - The final report will be consistent with the guidance contained in RG 1.20 Rev 3, Section C.2.4(2) which states: "...final report should include the following information:

   (a) description of any deviations from the specified measurement and inspection programs, including instrumentation reading and inspection anomalies, instrumentation malfunctions, and deviations from the specified operating conditions

   (b) comparison between measured and analytically determined modes of structural response (including damping factors) and hydraulic response (including those parameters from which the input forcing function is determined) for the purpose of establishing the validity of the analytical technique

   (c) determination of the margins of safety associated with operation under normal steady-state and anticipated transient conditions, including the margins of safety associated with any flow-excited acoustic or structural resonances

   (d) evaluation of unanticipated observations or measurements that exceeded acceptable limits not specified as test acceptance criteria, as well as the disposition of such deviations"

This report will provide the results of both the direct and indirect dryer monitoring and comparison against the predicted results using the ACM methodology as well as inspection results. The final report will be provided to the NRC within 180 days following completion of the first inspection, consistent with the guidance contained in RG 1.20 Rev 3, section C.2.5(5).

8 REFERENCES

1. BWRVIP-139-A, "BWR Vessel and Internals Project Steam Dryer Inspection and Flaw Evaluation Guidelines", EPRI 1018794, July 2009.

2. BWRVIP-181-A "BWR Vessel and Internals Project Steam Dryer Repair Design Criteria" EPRI 1020997, July 2010.

3. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.20, Revision 3, "Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing," March 2007.