Attachment 3

WCAP-17257-NP, Revision 4 (Non-Proprietary)

Westinghouse Non-Proprietary Class 3

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Revision 4

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STP Unit 4 Reactor Internals Flow-Induced Vibration Assessment Program

Westinghouse

WESTINGHOUSE NON-PROPRIETARY CLASS 3

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STP Unit 4 Reactor Internals Flow-Induced Vibration Assessment Program

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LIST OF ACRONYMS

ABWR	Advanced Boiling Water Reactor
BWR	Boiling Water Reactor
CFD	Computational Fluid Dynamics
CVAP	Comprehensive Vibration Assessment Program
FIV	Flow-Induced Vibration
NRC	Nuclear Regulatory Commission
RIP	Reactor Internal Pump
RG	Regulatory Guide
STP	South Texas Project

EXECUTIVE SUMMARY

The STP Unit 4 nuclear power plant will be the second ABWR constructed in the US, and is expected to be completed following completion and startup of STP Unit 3. ABWRs have been successfully operating since 1996 in Japan. There are four similar ABWRs currently operating and two more units under construction in Japan. In addition, two other ABWRs are under construction in Taiwan.

US NRC RG 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing" (Reference 1), provides guidance for the comprehensive vibration assessment program (CVAP) for nuclear power plants during preoperational and initial startup testing. The program is intended to demonstrate that the reactor internals are adequately designed to withstand flow induced vibration (FIV) effects at normal and transient plant operating conditions for design life of the plant. The latest revision of RG 1.20 (Revision 3) issued in March 2007 contains additional guidance for FIV assessment programs based on recent BWR experiences on steam dryers. Because the startup testing of the Japanese ABWRs occurred prior to the added guidance, it was decided that the STP Unit 3 plant will be designated as the prototype US ABWR plant requiring a CVAP. Because the reactor internals for STP Unit 4 are identical in arrangement, design, and size, and will have identical operating conditions to STP Unit 3, STP Unit 4 is designated as a non-prototype Category I reactor. The successful completion of the comprehensive vibration assessment program of STP Unit 3 will result in STP Unit 3 being the valid prototype, and the vibration assessment program for STP Unit 4 relies on this valid prototype.

The elements of the vibration assessment program for STP Unit 4 are (1) a vibration and stress analysis program, (2) an inspection program, and (3) an evaluation program. A measurement program is also performed for the STP 4 steam dryer. This report provides a roadmap for the STP Unit 4 vibration assessment program.

The vibration and stress analysis program is divided into two parts, the non-dryer reactor internals, and the steam dryer. The vibration and stress analysis program for the non-dryer reactor internals includes the determination of the FIV forcing functions, modal analysis, and uncertainties and biases associated with the analyses. The forcing functions were developed using various methods such as computational fluid dynamics (CFD) or simplified analyses. The stress analyses have been performed for the non-dryer components and are documented in WCAP-17371-P, "South Texas Project Units 3 and 4 Reactor Internals Non-Dryer Component Flow-Induced Vibration Assessment" (Reference 4).

The FIV qualification program for the dryer is described in WCAP-17385-P, "STP Unit 3 Steam Dryer Flow-Induced Vibration Assessment" (Reference 3). The approach used to qualify the steam dryer is (1) an assessment of the successful operating experience of two Japanese ABWRs, (2) the elimination of acoustic resonance, (3) a unit load analysis and finite element modeling to determine dryer instrumentation locations, and (4) a controlled power ascension plan with limit curve development based on in-situ steam dryer measurements. The Japanese ABWR operating experience is documented in WCAP-17369-P, "ABWR Dryer Operating Experience for STP Units 3 and 4" (Reference 6). Elimination of the acoustic resonance, the analysis to determine steam dryer instrumentation locations, and the power ascension plan and limit curve development methodology are described in Reference 3.

In addition, an analysis that confirms the results of the stress analysis that demonstrates structural acceptance of the reference Japanese ABWR dryer has been performed.

These four elements for steam dryer qualification along with the confirmatory stress analysis provide assurance that the steam dryer is adequately designed to withstand FIV forces, and satisfies the intent of RG 1.20 Revision 3.

Even though STP Unit 4 is designated as a non-prototype Category I reactor, the CVAP for Unit 4 will include a measurement program for the steam dryer. The STP Unit 4 steam dryer measurement program will be the same as the STP Unit 3 steam dryer measurement program as described in Reference 3 and Reference 5.

Per the guidance of RG 1.20, the inspection program for a non-prototype Category I plant should follow the same inspection program guidelines as for prototype reactor internals. The inspection program for STP Unit 4 will require inspection of the reactor vessel internals before and after preoperational testing to confirm structural integrity of the reactor vessel internals to withstand FIV with no damage to reactor internals or loose parts resulting from the testing. Additionally, the steam dryer will be inspected before initial installation and no later than the first refueling outage.

This program satisfies the guidelines of RG 1.20 Revision 3 for non-prototype Category I reactor internals.

1 INTRODUCTION

1.1 OVERVIEW

The purpose of this report is to describe the methodologies and results of an FIV evaluation of the reactor vessel internal components for STP Unit 4. A CVAP will be implemented for the STP Unit 4 reactor vessel internals, in accordance with the guidance provided in US NRC RG 1.20 Revision 3 (Reference 1). A description of the CVAP for STP Unit 3, which is considered to be the US ABWR prototype, is contained in Reference 2.

1.2 CLASSIFICATION

The STP Unit 4 reactor internals are identical in arrangement, design, and size, and will have identical operating conditions to STP Unit 3. The successful completion of the CVAP at STP Unit 3 will result in STP Unit 3 being the valid prototype, and the vibration assessment program for STP Unit 4 relies on this valid prototype. As the prototype, STP Unit 3 will include the vibration and stress analysis program, measurement program, inspection program, and associated evaluation program per the guidance of RG 1.20 (Reference 1). In accordance with the guidance of RG 1.20, the STP Unit 4 reactor internals are categorized as non-prototype Category I. The STP Unit 4 vibration assessment program includes the vibration and stress analysis program, and the inspection program. In addition, the vibration assessment program for STP Unit 4 will include a measurement program for the steam dryer. These programs are described in Sections 2 through 5.

1.3 VIBRATION ASSESSMENT PROGRAM COMPONENTS

The purpose of the vibration assessment program is to verify the structural integrity of the reactor internals subject to the possible effects of flow-induced vibration prior to commercial operation. The STP Unit 4 vibration assessment program is limited in scope as compared to the STP Unit 3 CVAP program, because the STP Unit 4 reactor internals are non-prototype Category I, and the STP Unit 4 vibration assessment program relies on the full CVAP of STP Unit 3.

Consistent with the guidance in Regulatory Position C.3.1 of RG 1.20 (Reference 1), the vibration assessment program for non-prototype Category I reactor internals includes the vibration and stress analysis program, and either a vibration measurement program or an inspection program. For STP Unit 4, the vibration assessment program is planned to include:

- vibration and stress analysis program, and
- inspection program.

In addition, the vibration assessment program for STP Unit 4 will include:

- measurement program for the steam dryer.

As described in RG 1.20, the results of the STP Unit 4 vibration and stress analyses and inspection program, and the steam dryer measurement program will be provided to the NRC in preliminary and final reports. The preliminary report will be provided within 60 days after completion of the inspections, and the final report within 180 days.

2 VIBRATION AND STRESS ANALYSIS PROGRAM

The STP Unit 4 reactor internals are identical in arrangement, design, and size, and will have identical operating conditions to STP Unit 3. An overview of the qualification program for the STP Unit 3 reactor internals, which is applicable to the STP Unit 4 reactor internals, is provided in Section 1 of Reference 2. The dryer qualification methodology is provided in Reference 3. The details of the analyses for the non-dryer components, including the methodology for and development of the forcing functions, and the determination of structural responses, including modal and stress analyses, are provided in Sections 5, 6 and 7 of Reference 4.

As noted in RG 1.20 Revision 3, the STP Unit 3 prototype vibration and stress analysis will be modified if necessary prior to performing the STP Unit 4 pre-operational testing to address any nominal (i.e. as-built) differences between the STP Unit 3 and STP Unit 4 reactor internals.

3 STEAM DRYER MEASUREMENT PROGRAM

The STP Unit 4 steam dryer is identical in arrangement, design, and size and will have identical operating conditions to STP Unit 3 and thus is designated as a non-prototype Category I component. Even though the STP Unit 4 steam dryer is a non-prototype Category I component, the Unit 4 vibration assessment program will include a measurement program for the steam dryer.

Instrumentation for the Unit 4 steam dryer will be the same as that for Unit 3, as described in Section 6.4.2 of WCAP-17256-P, "STP Unit 3 ABWR Prototype Reactor Internals Flow-Induced Vibration Assessment Program" (Reference 2).

The Unit 4 steam dryer measurement program will be the same as described in WCAP-17370-P, "South Texas Project Unit 3 Comprehensive Vibration Assessment Program Measurement, Test, and Inspection Plan" (Reference 5). Consistent with the Unit 3 instrumentation, each of the MSLs will be instrumented as described in Section 3.1.3 of Reference 5.

4 INSPECTION PROGRAM

The STP Unit 4 vibration assessment program requires inspection of the major reactor internal components prior to and after preoperational testing to confirm the structural integrity of the reactor internals to withstand FIV such that there is no damage to reactor internals or loose parts resulting from the testing. Additionally, the steam dryer will be inspected before initial installation and no later than the first refueling outage.

4.1 PREOPERATION INSPECTION

An inspection program is required in which a comprehensive set of inspections of the reactor internal components is carried out prior to and after preoperational testing. The preoperational testing conditions for the STP Unit 4 reactor internals are identical to those of the prototype, which are described in Reference 2. As described in Reference 2, the preoperational tests will be conducted with all internal components installed in the reactor except for the fuel assemblies, in-core instrumentation, and dryer. Tests will be conducted at zero power level. The pre-operational tests will cover flow rates from zero to 120%, and will include steady state flow conditions and flow sweeps over a wide range of flow rates. Operation will include the normal 10 RIPs running, as well as up to 3 non-operating RIPs. Coolant temperatures will range from room temperature up to 320°F. All pre-operational test conditions are sequentially listed in Table 1.3.1-1 of Reference 2. Reference 1 provides guidance that the internal components must accumulate a minimum of 10^6 cycles of vibration during the CVAP tests. Based on a bounding lower limit for component fundamental frequency of [ ]^{a,c}, the testing will require a minimum of [ ]^{a,c} of test time. This minimum testing period will assure that all internal components will reach at least 10^6 cycles. The test duration is sufficient to assure that the reactor internal components have been subjected to a minimum of 10^6 cycles of vibration before the post test inspection.

The inspection program will examine and document the condition of mating surfaces of the reactor internals at all critical interfaces. Specific locations will be inspected for evidence of contact and wear for effects of vibration. These locations include contact and potential contact surfaces between the major load bearing components, highly stressed locations identified in the analysis program, and specific welds. The inspections performed after preoperational testing will be performed prior to fuel load. Details of the preoperational inspection program for STP Unit 4 are identical to those for STP Unit 3, which are described in WCAP-17370 (Reference 5). The scope of the inspection for STP Unit 4 is identical to that defined in Section 5.1 of Reference 5.

4.2 STEAM DRYER INSPECTION

The steam dryer will be subjected to dynamic loading resulting from the steam flow turbulence, acoustic pressure pulsation and other sources of excitation during power operation. Hence, the steam dryer will undergo final inspection no later than the first refueling outage.

The prototype STP Unit 3 steam dryer will be inspected no later than after the first cycle of operation as discussed in Section 5 of Reference 5.

The inspection program for the STP Unit 4 steam dryer will be performed as a visual examination (VT-1). The steam dryer components and the areas to be inspected are the same as for the STP Unit 3 steam dryer and are listed in Table 5.2-1 of Reference 5. The locations of those components on the steam dryer are shown in Figure 5.2-1 of Reference 5.

5 CONCLUSIONS

The STP Unit 4 reactor internals are identical in arrangement, design, and size, and will have identical operating conditions to STP Unit 3. Thus, Unit 3 will be the valid prototype for the Unit 4 reactor internals. Westinghouse/Toshiba has evaluated the STP Unit 3&4 reactor internal components for FIV during testing, and normal operating and anticipated transient conditions as documented in References 2, 3, and 4. The evaluations show that the vibration levels of the reactor internal components are acceptable and that the STP Units 3&4 internals design is adequate to ensure structural integrity. These conclusions will be confirmed by a detailed power ascension program for STP Units 3&4.

The recommendations of NRC RG 1.20, Revision 3 (Reference 1) will be satisfied for STP Unit 4 by surface inspections of the reactor internal components before and after preoperational testing, and by visual examination of the steam dryer no later that after the first cycle of operation. In addition, measurements of the steam dryer will be performed during startup. In conjunction with the successful qualification of STP Unit 3 as a valid prototype, successful completion and documentation of these inspections and steam dryer measurements, and submittal of the preliminary and final reports to the NRC in accordance with Regulatory Position 2.5 paragraph (5) of RG 1.20 will constitute completion of the vibration assessment program for the non-prototype Category I STP Unit 4 reactor internal components.

6 REFERENCES

1. US NRC Regulatory Guide 1.20, Rev. 3, "Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing," March 2007.

2. WCAP-17256-P, Revision 5, "STP Unit 3 ABWR Prototype Reactor Internals Flow-Induced Vibration Assessment Program," Westinghouse Electric Company LLC, April 2013.

3. WCAP-17385-P, Revision 5, "STP Unit 3 Steam Dryer Flow-Induced Vibration Assessment," Westinghouse Electric Company LLC, April 2013.

4. WCAP-17371-P, Revision 6, "South Texas Project Units 3 and 4 Reactor Internals Non-Dryer Component Flow-Induced Vibration Assessment," Westinghouse Electric Company LLC, April 2013.

5. WCAP-17370-P, Revision 6, "South Texas Project Unit 3 Comprehensive Vibration Assessment Program Measurement, Test and Inspection Plan," Westinghouse Electric Company LLC, April 2013.

6. WCAP-17369-P, Revision 1, "ABWR Dryer Operating Experience for STP Units 3 and 4," Westinghouse Electric Company LLC, February 2013.