Attachment 3

WCAP-17370-NP, Revision 4 (Non-Proprietary)

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Revision 4

February 2013

South Texas Project Unit 3 Comprehensive Vibration Assessment Program

Measurement, Test, and Inspection Plan

Westinghouse

WESTINGHOUSE NON-PROPRIETARY CLASS 3

WCAP-17370-NP
Revision 4

South Texas Project Unit 3 Comprehensive Vibration Assessment Program Measurement Test and Inspection Plan

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ABWR Licensing

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ACRONYMS

ABWR	Advanced Boiling Water Reactor
AC	Accelerometer
BWR	Boiling Water Reactor
CRD	Control Rod Drive
CRDH	Control Rod Drive Housing
CRGT	Control Rod Guide Tube
CVAP	Comprehensive Vibration Assessment Program
COLA	Combined License Application
DCD	Design Control Document
DP	Differential Pressure
FIV	Flow-Induced Vibration
FSAR	Final Safety Analysis Report
HPCF	High Pressure Core Flooder
ICGT	In-core Guide Tube
ICM	In-core Monitoring
ICMH	In-core Monitor Housing
LVDT	Linear Variable Differential Transformer
LPFL	Low Pressure Flooder
MI	Mineral Insulated
MSL	Main Steam Line
MTI	Measurement, Test and Inspection
NRC	U.S. Nuclear Regulatory Commission
pC	Pico-Coulomb
psi	Pounds per Square Inch
PT	Pressure Transducer
RG	Regulatory Guide
RIP	Reactor Internal Pump
RJ-ABWR	Reference Japanese ABWR
RPV	Reactor Pressure Vessel
SG	Strain Gage
SRV	Safety Relief Valve
STP	South Texas Project

1 EXECUTIVE SUMMARY

South Texas Project Unit 3 (STP Unit 3) is the first Advanced Boiling Water Reactor (ABWR) being built in the U.S. It has been designated as a prototype plant and requires a comprehensive vibration assessment as specified in U.S. NRC Regulatory Guide (RG) 1.20, Rev. 3 (Reference 1). The comprehensive vibration assessment program (CVAP) demonstrates that the reactor vessel internals are adequately designed to withstand flow induced vibration (FIV) forces at normal and transient plant operating conditions for the plant design life.

The CVAP, applicable to STP Unit 3 as a prototype reactor, consists of a vibration and stress analysis program, a vibration measurement program during initial plant startup with and without fuel, and an inspection program. The overall CVAP details are contained in WCAP-17256-P.

This report covers the vibration measurement, test, and inspection (MTI) parts of the CVAP. The primary areas of MTI covered in this report include components to be instrumented and their basis, quantity and types of transducers on each component, transducer specifications, test conditions for collecting vibration data during preoperational and startup testing, data acquisition and analysis, and inspection details.

2 INTRODUCTION

STP Unit 3 is the first ABWR being built in the U.S. There are four similar ABWRs currently operating in Japan and two more units under construction. In addition, two other units are under construction in Taiwan.

US NRC Regulatory Guide (RG) 1.20, Comprehensive Vibration Assessment Program for Reactor Internals during Preoperational and Initial Startup Testing 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) forces at normal and transient plant operating conditions for design life of the plant. The latest revision (Revision 3, March 2007) of the RG 1.20 contains additional requirements based on recent Boiling Water Reactor (BWR) experiences on the steam dryers. Hence, it was decided that the STP 3 plant will be designated as a prototype plant requiring a comprehensive vibration assessment program (CVAP). Kashiwazaki-Kariwa Unit 6, herein referred to as the reference Japanese ABWR (RJ-ABWR), commenced successful commercial operation in 1996 and went through extensive testing to show that the reactor internals are adequately designed to withstand FIV loads. Because reactor internals in STP Unit 3 are the same as the RJ-ABWR internals, the results of the RJ-ABWR preoperational and startup tests are used as guide to establish the CVAP for STP Unit 3.

The CVAP, applicable to STP Unit 3 as a prototype reactor, consists of a vibration and stress analysis program, a vibration measurement program, an inspection program, and an evaluation program that will be implemented when the plant starts for the first time. The vibration and stress analysis program involves predictive stress analysis of reactor vessel internals susceptible to FIV. The measurement program consists of instrumenting selected internal components with vibration transducers that include strain gages, accelerometers, Linear Variable Differential Transformers (LVDTs) to measure displacement, and dynamic pressure transducers for collecting and analyzing the data at selected plant operating conditions during preoperational testing (prior to fuel load), precritical after fuel load and initial plant startup (power ascension after fuel load). This data is used for comparative analyses to determine if the measured stress levels are acceptable for long term plant operation. The inspection program requires examination of the reactor vessel internals before and after preoperational testing to confirm the structural integrity of the reactor vessel internals to withstand FIV with no damage to reactor internals or loose parts resulting from the testing.

STP Units 3 & 4 Combined License Application (COLA) Rev. 4, Part 2, Tier 2, Subsection 3.9.2.3, Dynamic Response of Reactor Internals Under Operational Flow Transients and Steady-State Conditions, discusses the program to properly evaluate potential FIV effects on reactor vessel internals during normal reactor operations and anticipated operational transients. COLA Subsection 3.9.2.4, Preoperational, Pre-critical and Initial Startup Flow-Induced Vibration Testing of Reactor Internals, discusses the reactor internals vibration measurement and inspection program, including the testing phases, transducer types and their location on internal components, visual inspections, and compliance with additional provisions of RG 1.20, Rev. 3 covering the main steam lines and steam dryer instrumentation and measurements. COLA Subsection 3.9.7.1, Reactor Internal Vibration Analysis Measurement and Inspection Program, further defines actions necessary to meet the provisions of RG 1.20, Rev. 3. These actions affect the vibration and stress analysis program; the MTI program; and documentation of results.

This report describes the MTI plan and documentation activities of the CVAP.

3 MEASUREMENT PLAN

This section provides a planning overview for the selection of major components for vibration measurement, specifying the type of vibration transducers and their installation, signal conditioning and data acquisition system, and analysis of that data.

3.1 COMPONENTS TO BE INSTRUMENTED AND LOCATION OF TRANSDUCERS

3.1.1 Non-Steam Dryer Components

Several STP Unit 3 ABWR internal components susceptible to FIV during plant operation were analyzed per RG 1.20, Rev. 3 (Reference 1) and are reported in Reference 4. Various components were selected for vibration measurement during preoperational, precritical and startup testing based on the following factors:

- Field cracking experience: Components which have experienced FIV related cracking in prior ABWR or where applicable, BWR operation
- Stress results of similar tests conducted on an RJ-ABWR (Reference 2)
- Safety significance
- Difficulty of installation and subsequent removal of instrumentation following startup testing
- Calculated alternating stresses

Of the above factors, the results of the calculated alternating stresses is somewhat less significant since stress analysis is often done with conservative assumptions and the results do not always indicate the actual stresses on the component. If subsequent detailed analysis indicates the calculated stress levels are high, these components may be added to the instrumentation plan.

COLA FSAR Subsections 3.9.2.3, 3.9.2.4, and 3.9.7.1 list the following components to be selected for FIV measurement during initial plant startup:

- Top of shroud head,
- Top of shroud,
- Control rod drive guide tube/housing (CRGT/CRDH),
- In-core guide tube (ICGT),
- In-core monitor housing (ICMH),
- High pressure core flooder (HPCF) coupling and,
- High pressure core flooder sparger.

In addition, dynamic pressure transducers will be installed in the annulus region between the shroud and the reactor pressure vessel (RPV) to confirm the forcing functions and bench mark the pressure pulsation measurements against the RJ-ABWR. The pressure signals to be measured are pressure pulsation due to turbulence and acoustics arising from reactor internal pump (RIP) rotation subcomponents.

This plan includes a list of expected preliminary components selected for instrumentation, type of measurement to be made, vibration transducer type, and quantity to be installed. Transducer location on the component, transducer orientation, and location basis are listed below in Table 3.1.1-1. This list is

subject to change as necessary based on any future FIV analyses. Additionally, the exact location (azimuth and elevation details) for transducer placement will be decided during instrumentation design after considering details such as installation and removal limitations, interference from other components, and transducer cable routing.

The planned locations of strain gages, accelerometers, LVDTs, and dynamic pressure transducers on the selected components are shown in Figure 3.1.1-1 through Figure 3.1.1-6.

Table 3.1.1-1 Preliminary Selection of Components for CVAP Instrumentation and Transducer Location for Non-Dryer Components

a,c

Item	Component Name	Type of Measurements	Sensor Type and Quantity	Sensor Location	Sensitive Direction and Orientation	Reasons for Selection
1	Top of Shroud Head					
2	Top of Shroud					
3	CRGT/CRDH					
4	ICGT					
5	ICMH					

Table 3.1.1-1 Preliminary Selection of Components for CVAP Instrumentation and Transducer Location for Non-Dryer Components (cont'd)

a,c

Item	Component Name	Type of Measurements	Sensor Type and Quantity	Sensor Location	Sensitive Direction and Orientation	Reasons for Selection
6	HPCF Coupling and Thermal Ring					
7	HPCF Sparger					
8	Annulus Area (between shroud and RPV)					

a,c

Figure 3.1.1-1 Planned CVAP Transducer Locations

a,c

Figure 3.1.1-2 Planned Strain Gage Locations on Control Rod Guide Tube

a.c

Figure 3.1.1-3 Planned Strain Gage Locations on In-Core Guide Tube

[ ] a,c

Figure 3.1.1-4 Planned Strain Gage Locations on In-Core Monitor Housing

a,c

Figure 3.1.1-5 Planned Strain Gage Locations on High Pressure Core Flooder Sparger

a,c

Figure 3.1.1-6 Planned Strain Gage Locations on High Pressure Core Flooder Coupling

3.1.2 Steam Dryer

The steam dryer is subjected to dynamic loading resulting from the steam flow turbulence, acoustic pressure pulsation and other sources of excitation during plant operation. The steam dryer will be instrumented with dynamic pressure transducers (PT), strain gages (SG) and accelerometers (AC) to measure vibration as specified in RG 1.20, Rev. 3 (Reference 1). The dryer instrumentation plan details and the structural loading evaluation methodology during plant startup are described in Reference 7. The RJ-ABWR steam dryer was also instrumented during initial plant startup and had shown acceptable vibration levels. The inspection of the RJ-ABWR after several years of operation has confirmed structural integrity of the steam dryer (Reference 8).

The instrumentation plan for the STP-3 dryer includes [ ]^{a,c}. The planned location of the pressure transducers are shown in Table 3.1.2.1-1.

3.1.2.1 Pressure Transducer Locations on the Dryer

The locations of dynamic pressure transducers on steam dryer components are shown in Figure 3.1.2.1-1 and Figure 3.1.2.1-2. There will be [ ]^{a,c}, for a total of [ ]^{a,c} sensors. [ ]^{a,c} will be aligned with [ ]^{a,c}. The remaining [ ]^{a,c} will be located towards the [ ]^{a,c}. There will be [ ]^{a,c}. The location will be similar to the corresponding sensor in RJ-ABWR. In addition, there will be [ ]^{a,c}.

The dryer skirt will have a total of [ ]^{a,c}. [ ]^{a,c} All of the [ ]^{a,c} will be located [ ]^{a,c}.

Table 3.1.2.1-1 Steam Dryer Sensors Location and Basis

Dryer Component name	Sensor Location	Sensor Quantity			Location Basis/ Comments

a,c

Table 3.1.2.1-1 Steam Dryer Sensors Location and Basis (cont'd)

Dryer Component name	Sensor Location	Sensor Quantity			Location Basis/ Comments

a,c

a,c

Figure 3.1.2.1-1 Planned Pressure Transducer Location on the Dryer [ ]a,c

a,c

Figure 3.1.2.1-2 Pressure Transducer Location on the Dryer [ ]a,c

3.1.2.2 Strain Gage Locations on the Dryer

The locations of strain gages (SG) on steam dryer components are shown in Figures 3.1.2.2-1 through Figure 3.1.2.2-4. [

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[

]a,c

[

]a,c

[

]a,c

[ ]a,c

Figure 3.1.2.2-1 Dryer Strain Gages on [

]a,c.

[ ]a,c

Figure 3.1.2.2-2 Dryer Strain Gages on [

]a,c

[ ]a,c

Figure 3.1.2.2-3 Dryer Strain Gages on [ ]a,c

[ ]a,c

Figure 3.1.2.2-4 Dryer Strain Gages on [ ]a,c

3.1.2.3 Accelerometer Locations on the Dryer

[ ][a,c] accelerometers will be placed near [ ][a,c]. The purpose of these sensors is [ ][a,c]. The location of these [ ][a,c] accelerometers is shown in Figure 3.1.2.3-1.

[ ] a,c

Figure 3.1.2.3-1 Accelerometer Locations on the Dryer Support Ring (viewed from 90° side).

3.1.3 Main Steam Lines and Safety Relief Valves

RG 1.20, Rev. 3 (Reference 1) specifies instrumentation of main steam lines (MSLs) and safety relief valves (SRVs) during plant startup. The MSL SRVs will be designed [ ]^{a,c} during plant operating conditions. In addition, the MSLs will be instrumented [

]^{a,c}

Main steam lines A, B, C, and D will be instrumented with [
]^{a,c} strain gages are planned for [
]^{a,c}. The transducers at each location will be installed circumferentially at equally spaced intervals to measure hoop stress caused by steam pressure pulsations.

At each location, the strain gages that are diametrically opposite to each other along the circumference will be combined to form opposite arms of a Wheatstone bridge circuit. In this configuration, the hoop strain from each of the two strain gages will be additive. This will minimize any strain contribution due to bending.

The vertical distance between the two transducer locations is based on SRV acoustics calculations. Sufficient distance from welded joints, pipe bends, tees, pipe supports, and other welded attachments will be provided.

[

]^{a,c}

3.1.4 Transducer Types

The following types of transducers are planned for installation on components previously identified for vibration and dynamic pressure measurements:

- Strain gages (uniaxial, weldable),
- Accelerometers (uniaxial, piezoelectric),
- LVDT to measure relative displacement, and
- Dynamic pressure sensors (piezoelectric).

The above transducers are not intended for permanent plant monitoring; their purpose is to measure vibration and dynamic pressures during initial plant startup lasting only a few months. The transducers located on [ ]^{a,c} and their associated hardware are planned for removal prior to fuel load. However, the remaining instrumentation, which includes the sensors on [ ]^{a,c} will be removed during the first refueling outage after one operating cycle. Any transducer or hardware that is not removable will be designed to remain installed for the plant operating life. As designed, these transducers are expected to be functional in a reactor environment for a period of four to six months, at which time the startup measurements will be completed.

Selection criteria for the transducers are based on desired response, prior application in BWR, ABWR or PWR environment, and performance and reliability.

3.1.5 Transducer Specifications

The following specifications are applicable to all of the transducers listed in Section 3.1.4:

Application:	ABWR internals vibration monitoring
Static Pressure:	1050 psia, maximum
Operating Temperature:	68°F to 550°F, maximum
Surrounding Medium:	Boiling water/steam
Radiation Tolerance:	Integrated gamma flux: 10^{10} erg/gram, typical Integrated neutron flux: 10^{16} n/cm^2, typical
Additional Requirements:	Transducer and cable shall be hermetically sealed. Transducer outer casing and cable sheath shall be made of stainless steel type 304, 321, 316L or Inconel 600 suitable for reactor internal application. The cable shall have mineral insulation approved for the reactor environment. The minimum insulation resistance of sensors is 10^9 ohms at 77°F and 10^7 ohms at 550°F.

Transducer sensitivity and measuring range (typical):

Strain Gages:	Gage factor: 1.5 or greater Dynamic measuring range: +/-1500 micro-strain, maximum Frequency response: 3 Hz to 500 Hz
Accelerometers:	Sensitivity: 10 pC/g or greater, typical Dynamic measuring range: +/-100 g, maximum Frequency response: 3 Hz to 2500 Hz
Dynamic Pressure Transducers:	Sensitivity: 13 pC/psi or greater, typical Dynamic measuring range: +/-50 psi, maximum Frequency response: 3 Hz to 2500 Hz
LVDT:	Sensitivity: 50 mV/mil, typical Dynamic measuring range: = +/-200 mils Frequency response: DC to 200 Hz

3.2 TRANSDUCER DESIGN AND INSTALLATION

The quantity and placement of the transducers on selected components is normally based on sensitivity to expected vibration modes, redundancy in case of failure, installation difficulties, and transducer removal considerations. The installation method will be designed so the attachment of the transducer to the structure does not fail for the plant operating conditions. The transducer leads will be attached to the structure using stainless steel clips and brackets at pre-determined intervals to eliminate susceptibility for vortex shedding resonance. Most of the leads (mineral insulated (MI) cables) will be routed in stainless steel conduits for mechanical protection to prolong their survival in a reactor environment and for ease of removal after completion of startup testing.

Transducer insulation resistance will be measured at different stages of installation to assess the condition of the transducers during the installation process. Position of the installed transducers will be measured to compare with intended locations based on the installation documents. In addition, photographic records will be maintained for all installed transducers and cable routing as part of the quality assurance program. These records are useful for comparative purposes and for transducer removal at the end of the program. After completing installation, response tests will be performed by exciting the structure or transducers to confirm they are functional.

3.3 TRANSDUCER REDUNDANCY

The selection of transducers for STP Unit 3 vibration and pressure measurement will include the design requirements for their severe reactor environment. However, it is expected that some transducers may not survive the duration of startup testing. This expectation is taken into account through the selection of the number of transducers located on each component to ensure redundancy among the transducers. Conservatively assuming [

]^{a,c}.

[

]^{a,c}

[

]^{a,c}

3.4 TRANSDUCERS AND SIGNAL CONDITIONING REQUIREMENTS

Transducers

All transducers (with the MI cables) are planned for testing in an autoclave at reactor pressure and temperature for several hours. Insulation resistance will be measured at elevated temperature and pressure at different times to assure survivability requirements. Transducers meeting the minimum required criteria will be selected for installation. They will be calibrated and traceable to approved calibration standards. Sensitivity deviation at elevated temperatures will be incorporated into the calibration procedures to improve measurement accuracy.

Signal Conditioning

Strain gages require suitable excitation and bridge completion circuits to extract the strain signals. The strain gage amplifiers will be selected to provide sufficient gain to measure very low strain levels and will have selectable low pass filters. The desired frequency range for the strain gage system is from 0 Hz to 500 Hz. The strain gages are susceptible to electrical noise pickup in the plant environment and care will be exercised to minimize the noise levels. Using twisted shielded cables, shielded drywell penetrations, proper grounding methods and an isolation transformer to supply power will further reduce the signal noise levels. Additional noise reduction will be performed digitally by post processing the acquired data.

Accelerometers and dynamic pressure transducers for high temperature applications will be piezoelectric charge type devices that require remote charge converters. The charge converters will be located as close as practical to the transducers to minimize electrical noise intrusion. The charge converters will be located in the drywell and housed in metal enclosures for protection against moisture. The accelerometer signal conditioning amplifiers will have sufficient gain and double integration capability to measure displacement on the order of a few mils. Alternately, the acceleration signals can be converted to displacement digitally by the computerized data acquisition system. The accelerometer and pressure transducers will have a frequency response from 3 Hz to 800 Hz or better.

Data Acquisition System

The data acquisition system will consist of signal conditioning, data recording, and data analysis equipment. The data acquisition system includes a computer with spectral analysis software to perform frequency and time domain analysis in real time and off-line from recorded data. The raw and analyzed data will be saved and stored on removable storage media for archival or transmittal. The data acquisition system computer will be connected to an approved network for communication and data transmission.

3.5 DATA ACQUISITION AND ANALYSIS

With all the transducers installed and field wiring completed, field calibration will be performed for each channel prior to data acquisition. Baseline data will be collected to determine the channel noise level.

Signals from strain gages, accelerometers, LVDTs, and pressure transducers will be recorded and analyzed on-line. The data will be recorded simultaneously for all test conditions. The duration of the data recording is normally five minutes for each steady state test condition. For transient testing such as pump trips and generator load rejection, the data collection is planned to begin [ ]^{a,c} after the transient event. For each test condition, plant parameters such as reactor thermal power, generator output power, core flow, steam flow, feed-water flow, number of RIPs operating, RIP speed, reactor temperature, reactor pressure, reactor water level, core plate DP, and percentage rod-line will be recorded. The vibration data will be correlated with selected plant parameters for trending and projection.

The data acquisition system will have a sufficient sampling rate to accommodate signal frequency ranges up to 1000 Hz or higher. On-line and off-line spectral analysis and time history analysis will be performed for all test conditions to determine the amplitude and frequency content of the vibration signals. The measurements will be compared to the established criteria for each strain gage, accelerometer and LVDT and detailed documents will be prepared at a later time prior to fuel load. The documents include design specifications, drawings, test plans, procedures, and acceptance criteria. The acceptance criteria will be based on the allowable vibratory stress limit for the instrumented components and the installed location of the transducer.

Steam dryer data collection and evaluation will be performed, starting at an approximate 60% power level. The details regarding the test conditions and data evaluation methodology for analyzing the stream dryer load is described in Reference 7.

3.6 BIAS ERRORS AND UNCERTAINTIES FOR THE MEASUREMENT SYSTEM

Bias errors and uncertainties will be determined based on the type of transducer used, frequency response, sensitivity deviation with temperature, signal conditioning and data acquisition system calibration, and other parameters. Measurement uncertainties will be reported in the test report issued after plant start-up testing. It is expected that the measurement uncertainties [ ]^{a,c}. Transducer sensitivity deviation with temperature and gage factor variation will be taken into account during data acquisition and calibration to reduce uncertainty in the measurement.

4 CVAP TEST CONDITIONS

The CVAP test conditions consist of steady state and potential transient conditions that could be experienced during reactor operation, such as RIP startup, trips, plant shutdowns, and generator load rejection. The steady state test conditions are more important in terms of the FIV perspective because the longer duration of plant operation could result in the accumulation of very large vibration cycles.

When RJ-ABWR was built, it was tested extensively for FIV in a wide range of steady state and transient conditions. The details and the results are shown in Reference 2. STP Unit 3 is the same as the RJ-ABWR; hence the results of the RJ-ABWR tests were used as guidance in selecting STP Unit 3 test conditions. Justification for the selection of CVAP test conditions are contained in Reference 3.

Testing will be performed in three phases: preoperational testing, precritical testing (after fuel load but prior to achieving reactor criticality), and initial startup testing. Preoperational flow testing will be performed prior to fuel load. Precritical testing will be performed after fuel load, but before reactor criticality, and initial startup testing will be performed during power ascension. More detailed test conditions will be prepared in the future as the plant startup test procedures become available.

4.1 PREOPERATIONAL TESTING

Preoperational testing will be conducted prior to fuel loading with all internal components installed with the exception of fuel assemblies, in-core instrumentation, and the steam dryer. The selected steady state and transient test conditions for preoperational testing are listed in Table 4.1-1. [

]a,c

Table 4.1-1 Preoperational Test Conditions

Item	Test Condition	No. of RIPs ON		Notes
		Start	End	
1				
2				
3				
4				
5				
6				
7				
8				

a,c

The planned test duration is a few days. The duration of the test will be such that the lowest natural frequency component will accumulate 10^6 cycles to reach the endurance limit. Therefore, the resulting vibratory cycles are in excess of 10^6 cycles for vibration of major reactor internal components at their lowest dominant response frequencies.

4.2 PRECRITICAL TESTING WITH FUEL

Precritical testing will be performed with fuel prior to reactor criticality with all components installed and reactor assembly complete. The selected test conditions for Precritical testing are listed in Table 4.2-1.

Table 4.2-1 Precritical Test Conditions

Item	Test Condition	No. of RIPs ON		Notes*
		Start	End	
1				
2				
3				
4				
5				
6				

a,c

[ ]a,c

4.3 STARTUP TESTS

Startup tests will be performed with fuel in place and reactor assembly complete in all respects and after rector achieved criticality. The first startup testing at power is planned after the reactor reaches normal operating temperature and pressure and rod line between approximately 50% and 75%, and at 100%. The selected test conditions for startup testing are listed in Table 4.3-1.

Table 4.3-1 Startup Test Plan

Item	Test Condition	No. of RIPs ON		Notes
		Start	End	
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

a,c

5 INSPECTION PROGRAM

The CVAP requires inspection of the major reactor internal components prior to and after preoperational testing. The inspection confirms the structural integrity of the reactor internals to withstand FIV, and that the testing does not damage reactor internals or result in loose parts. Additionally, the steam dryer will be inspected before initial installation and no later than the first refueling outage.

5.1 INSPECTION DETAILS

The inspection program for STP Unit 3 involves visual examination (VT-3) of critical reactor internal components susceptible to FIV prior to and after preoperational testing to confirm that the structural integrity is maintained. During preoperational testing, the reactor internals will be subjected to different flow conditions from flow sweeps, steady state operation, pump trips and unbalanced flow by tripping selected RIPs. In addition, the tests include several hours of continuous high core flows at or above rated core flow; the resulting vibratory cycles are in excess of 10^6 cycles for vibration of major reactor internal components at their lowest dominant response frequencies.

Initial inspections will be performed on all components listed in Table 5.1-1 prior to pre-operational testing with some components not installed to allow for inspection access. At the completion of the pre-operational testing, the vessel head and the shroud head will be removed and the vessel drained. The inspection will be repeated on the same components after the flow testing prior to fuel load. Figure 5-1 shows the planned reactor internal components and the areas to be inspected.

The inspection includes assessment for any cracking of the welds or components, deformation, loosening of bolts, presence of debris, and component failures resulting from FIV and wear. A direct close up VT-3 inspection will be performed on most components with magnification required. For those components not accessible for up close inspection, binoculars, mirrors and remote video cameras will be used.

Detailed inspection procedures will be prepared taking into consideration applicable safety and quality requirements. The results of the examinations at each location will be recorded in the form of notes, photos, and video files and will be maintained for evaluation and reporting. If there is any indication of cracks, loose parts, debris, unusual wear or other abnormal conditions, the responsible groups will be notified for further evaluation and disposition.

Table 5.1-1 Planned Inspection Locations Prior to and After Preoperational Testing

Item	Components for Inspection	Inspection Areas
1	CRGT, CRD Housing and Lower Plenum	CRD housing to stub tube weld, RPV to stub tube welds
		Lower plenum debris
2	ICGT, ICM Housing and Stabilizer	ICM housing to RPV welds
		ICM housing and ICGT welds
		In-core stabilizer welds
3	Differential Pressure (DP) Line	Core DP line and support bracket welds
		RIP DP line and support bracket welds
4	Core Shroud	Shroud and shroud support welds (inside)
		Shroud and shroud support welds(outside)
		Space between shroud and RPV
5	RIP	Upper surface of RIP, diffuser and impeller (for deformation and debris)
6	RIP Guide Rail	Welds between block and rail, shroud
		Deformation of guide rail
7	Core Plate	Tack welds of core plate stud
		Upper surface of core plate and presence of debris between core plate and shroud
8	Fuel Support	Lifting of orificed fuel support
		Surface of fuel support (wear and debris)
9	Top Guide	Top guide keeper and bolt tack welds
		Tack welding and surface of dowel pin and engagement pin
		Surface of top guide flange
		HPCF sparger welds (nozzle, bracket, T and elbow)
10	HPCF Coupling	Collar tack welds
		Thermal ring and top guide welds
		Welds between brace and pipe, top guide
		Piping welds
11	Feedwater Sparger	Bracket and end plate, T and nozzle welds
		Bolt tack welds

Table 5.1-1 Planned Inspection Locations Prior to and After Preoperational Testing (cont'd)

Item	Components for Inspection	Inspection Areas
12	LPFL Sparger	Welding of bracket and end plate, T and nozzle
		Tack welding of bolt
13	Surveillance Sample Holder	Surveillance holder and welds
14	Shroud Head and Separator	Upper and lower guide ring gusset welds, lifting rod tack welds to shroud head lugs
		Surface of outer separator (wear and deformation)
		Outer stand pipe and shroud head welds
15	Shroud Head Bolt	Surface of shroud head bolt
16	Steam Dryer	See Table 5.2-1
17	FIV Sensors, Cables, Conduits and Associated Hardware (not shown)	Sensor mount and conduit brackets tack welds
		Sensor leads and conduits

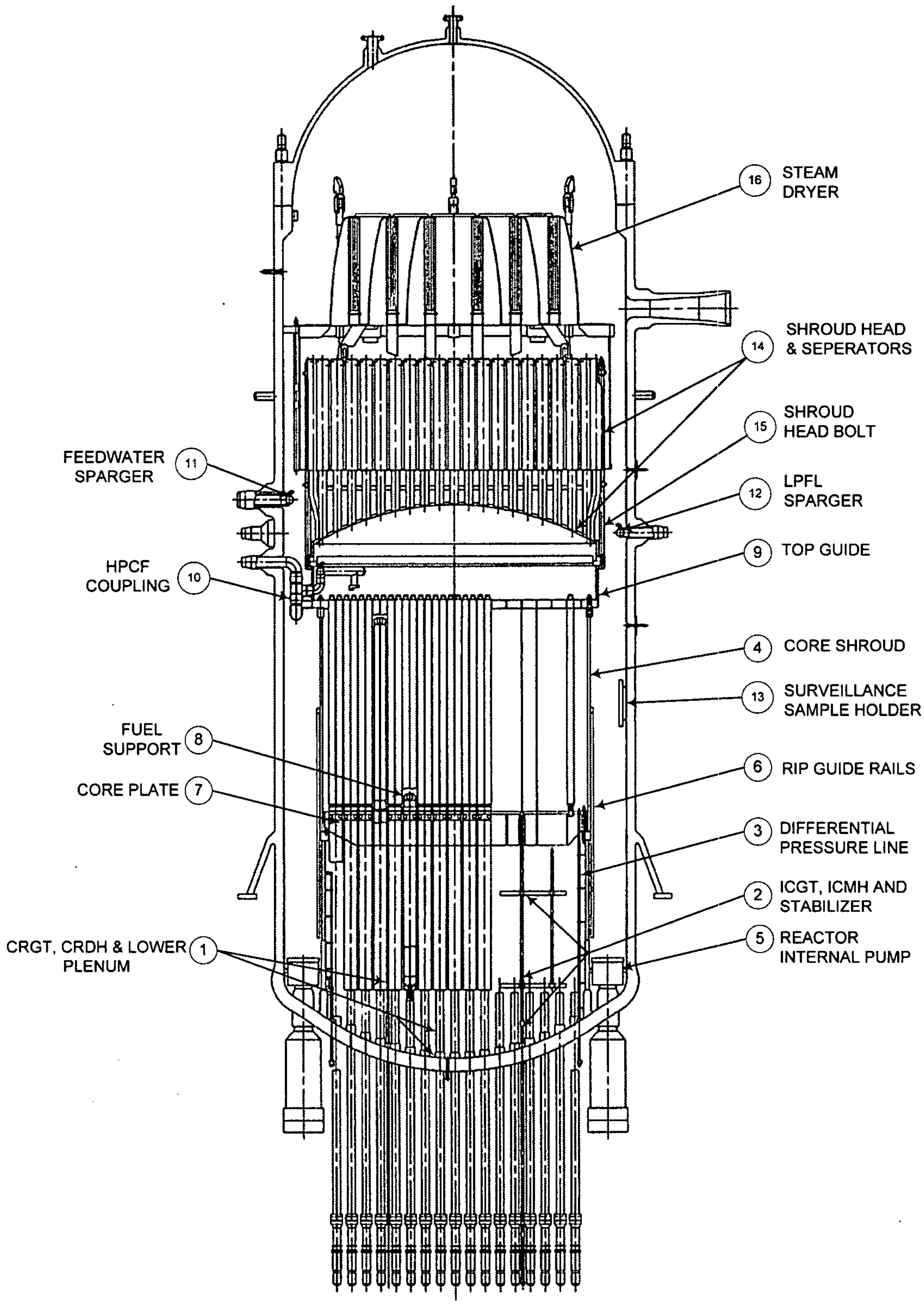

Figure 5-1 Planned Locations of Reactor Internal Components for Inspection

5.2 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. Therefore, the steam dryer will undergo final inspection no later than the first refueling outage. The ABWR steam dryer components and areas to be inspected are listed in Table 5.2-1. The locations of the steam dryer components are shown in Figure 5.2-1. Remote underwater cameras and binoculars are planned for use during this inspection and the inspection will be performed on the outer surface of the dryer. The plan to inspect only the outer areas of the dryer is consistent with BWR VIP-139A guidelines for curved hood design (Reference 6), which is also adopted for ABWR dryer design. The steam dryer inspection will be conducted in accordance with ASME Section XI and BWRVIP-139A guidelines (References 5 and 6). The visual inspection method planned for steam dryer components will be VT-1. The inspection will be performed no later than the first refueling outage. The resolution, distance, illumination and angle of view requirements will be maintained to the extent practical during VT-1 inspection. VT-1 examination is conducted to detect discontinuities and imperfections on the surface of components as well as the welded joints, including conditions such as cracks, wear, corrosion, or erosion.

The inspections performed on the steam dryers of two Japanese ABWRs after five years and 11 years of commercial operation (Reference 8) affirm integrity of the dryers; hence similar results are expected with STP Unit 3.

Table 5.2-1 Planned Inspection Locations on the Steam Dryer

Item	Component	Inspection Areas	Inspection Emphasis*
1	Outer Bank and Hood	Horizontal and vertical welds	1
		Hood surface	1, 3, 7
2	Middle Bank	Horizontal and vertical welds	1
		Between the banks	4
3	Central Bank	Horizontal and vertical welds	1
		Between the banks	4
4	End Plates	Weld around end plate	1
5	Cover Plate	Cover plate to support ring weld, cover plate to front hood weld	1
6	Manhole Cover (at 90°)	Manhole weld to cover plate	1
7	Tie Rods	All tie rod attachment welds on both ends	1
		All tie rods	1, 3
8	Drain Channels	Drain channel to skirt weld, drain channel to support ring weld	1
9	Dryer Skirt	Skirt welds to top support ring and lower ring	1, 7
		Skirt surface	3
10	Dryer Support Ring Assembly	Support ring weld all around	1
11	Seismic Block	Supporting surfaces	2
12	Lower Skirt Ring	Lower ring weld to skirt	1
		Ring geometry, surface	1, 3
13	Guide Rod Brackets	Bracket surfaces	2, 6
14	Lifting Rod Assembly	Eye plate	1, 5, 8
		Lifting rod collar weld	1
		Lifting rod	3, 5, 6
15	Hold-down Studs and Collars	Hold-down stud collars weld	1
		Hold-down rod	3, 5, 6
16	FIV Sensors, Cables, Conduits and Associated Hardware (not shown)	Tack welds for sensor mount and conduit brackets	1
		Sensor leads, conduits and hardware	1, 5, 6
17	Dryer Support Brackets (welded to RPV, not shown)	Bracket contact surface	1, 2, 6
18	Additional Components with High Stress Based on Analysis (not shown)	High stress location based on analysis	1, 6

Note:
* 1- Cracking, 2- Wear, 3- Deformation, 4- Debris, 5- Looseness, 6- Damage, 7- Scratches, 8- Evidence of movement or rotation

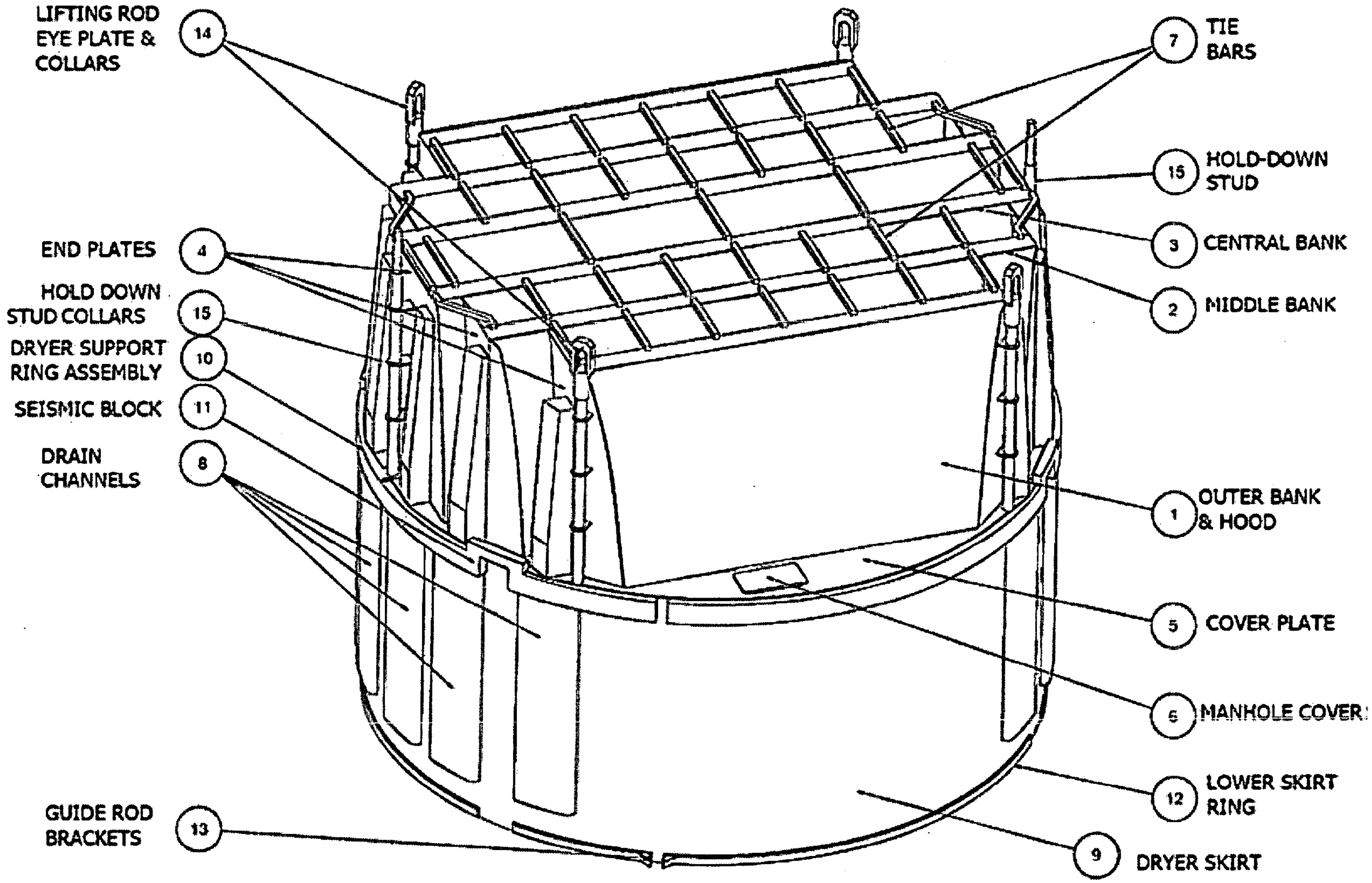

Figure 5.2-1 Planned Steam Dryer Components for Inspection

6 DOCUMENTATION OF RESULTS

The results of the vibration measurement and inspection program will be submitted to the NRC as specified in RG 1.20, Rev. 3 (Reference 1) in the form of preliminary and final reports.

The results of the vibration and stress analysis for the non-dryer components will be reviewed and correlated with the results of the measurement programs to determine the extent to which the test acceptance criteria were satisfied. Documentation of the results of the vibration measurement program will be included in the final report. The vibration measurement program results will include a comparison of the measured values to the acceptance criteria. The following actions will be performed as part of the vibration measurement program.

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7 ACCEPTANCE CRITERIA

7.1 BASES FOR ACCEPTANCE CRITERIA

Acceptance criteria will be developed for each of the sensors to be used during the CVAP. The categories of instrumentation include:

- Strain gages, to measure local strain values, for eventual use in determining stress values,
- Pressure transducers, to measure deterministic pump pulsations and turbulence levels, for comparison with predicted values,
- Accelerometers, to measure local component accelerations, for eventual use in determining component displacements,
- Displacement transducers, for direct measurement of component relative motion of components.

The acceptance criteria will focus exclusively on the dynamic responses of the structures related to flow-induced vibration. Acceptance criteria will be established, taking into account the location of the particular transducer, operating conditions for each test, uncertainties and biases, and margins to be added for conservatism to ensure that the allowable fatigue stress (9.95 ksi) will not be exceeded. Redundancy of the sensors is considered in the location and number of instruments.

Tables of maximum allowable test values will be generated for the sensors for use in the detailed test procedures. These maximum allowable test values will provide guidance for the test operators when they are conducting the CVAP tests. This information will allow the operators to determine the margins between the sensor values being measured and the maximum allowable test values as the tests are progressing.

Each of these components will have their own set of instrumentation to measure specific aspects (strains and significant frequencies) of flow-induced vibration characteristics for that component. Acceptance criteria will be developed for each set of instrumentation.

Two levels of acceptance criteria for allowable vibration will be used during the tests. Level 1 criteria are bounding type criteria associated with safety limits, while Level 2 criteria are associated with analysis predictions. For steady state vibration, the Level 1 criteria are based on the fatigue endurance limit (9.95 ksi) to assure no failure from fatigue over the life of the plant.

8 REFERENCES

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

2. Toshiba Document, RS-5126954 (Proprietary Class 2), Toshiba Corporation, "Prototype ABWR Reactor Internals Flow Induced Vibration Test Report," Japan, July 29, 2008.

3. Westinghouse Document, WCAP-17256-P, Rev. 4, "STP 3 ABWR Prototype Reactor Internals Flow-Induced Vibration Assessment Program," February 2013.

4. Westinghouse Document, WCAP-17371-P, Rev. 4, "South Texas Project Unit 3 and 4 Reactor Internals Non-Dryer Component Flow-Induced Vibration Assessment," February 2013.

5. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, 2007 Edition.

6. EPRI Technical Report 1018794 BWRVIP-139-A: BWR Vessel and Internals Project, "Steam Dryer Inspection and Flow Evaluation Guidelines," July 2009.

7. Westinghouse Document, WCAP-17385-P, Rev. 4, "STP Unit 3 Steam Dryer Flow-Induced Vibration Assessment," February 2013.

8. Westinghouse Document, WCAP-17369-P, Rev. 1, "ABWR Dryer Operating Experience for STP Units 3 and 4," February 2013.