Current

Summary of Hope Creek Vibration Issues and Planned Actions

Background and Overview

During operation of Hope Creek vibration issues have occurred which have been addressed through repairs, design changes and operational limits. This white paper summarizes these issues and provides an overview of the corrective actions that have taken place and that are planned in the future.

These issues include small bore pipe cracks from piping attached to the Recirculation System, loud noises in the drywell at pump speeds near the upper end of the control band, poor seal performance and vibration of the Recirculation Pump "B", vibration induced failures of components in the drywell and the potential of vibration damage from increased steam flows that will be achieved when the plant power level is increased after the Power Up-Rate Project.

These issues have raised concern whether the vibration of piping in the drywell is abnormal or above design limits. Measurement of the piping vibration during start-up and recently in 2004 has confirmed that the vibration of the piping systems is within design limits and will not cause fatigue induce failures to the main system piping. However, some damage has occurred in attached small bore piping which has been addressed by modifying support structures and enhancing the inspection plans for these welds.

Hope Creek has also performed the inspections of welds required by ASME Codes, NRC requirements and the Industry BWRVIP inspections as well as augmented inspections of the Recirculation Loop piping. These inspections have not revealed any indications of pipe cracking.

There is some history of small-bore pipe cracking that is believed to be vibration induced. Most of these events occurred early in plant life in the 1987 to 1989 time frame and were repaired and corrected by various modifications that improved the vibration resistance of these lines. In October 2001 a crack was found in an "A" Loop Recirculation Piping Instrument small-bore pipe. This was caused by attached hardware that changed the natural frequency of this line. The line was repaired and the hardware removed. In the present outage, radiography of this line showed an indication if an incipient crack. This inspection was done as a follow-up corrective action of these previous failures and detected the indication before a through wall crack developed. This joint will be replaced with a more robust design.

Details of each of these issues are provided below.

Recirculation Pump "B"

This pump has had a history of poor seal performance and higher shaft vibration levels than the "A" pump. Until the last seal replacement in February 2003 just prior to RF11 the poor seal performance was attributed to the higher vibration levels and a theory proposed by vendor representatives that a bowed shaft could contribute to the seal performance.

The root cause performed at this time discovered that the seal purge supply line relief valve had been a chronic leaking valve which would have starved this seal of the clean purge water and would explain the poor seal performance. After restoring the seal, replacing the relief valve and monitoring the leak off of the relief valve, the presently installed seal has performed well for the entire cycle.

The pump shaft bow will be characterized by measuring during RF12, if significant bow is detected, a plan will be developed to replace the shaft in a future outage. Since the pump is operating with satisfactory performance with regard to seal performance, it has been determined that continued operation will not be a safety or reliability risk. Additional work will be performed on the coupling to reduce the shaft vibration levels.

The following is the 'B' Reactor Recirculation Pump scope for RF12:

1. Replace the mechanical seal with a new (not refurbished) mechanical seal package. A Flowserve field representative will be present to support the disassembly and inspection of the removed mechanical seal package prior to the installation of the new mechanical seal package to find any applicable new information before the new mechanical seal is installed.
2. Install the mechanical seal leak-off line modification to ensure the mechanical seal leak-off goes to the drywell equipment drains as originally designed instead of to the drywell floor.
3. Re-machine pump coupling spacer. Machine the "egg" shape out of the lower coupling spacer flange. This was the cause of the 'B' Reactor Recirculation pump vibration indication inaccuracy, which previously gave the pump vibration levels of 21 mils.
4. Complete 'B' Reactor Recirculation pump shaft characterization:
   With the mechanical seal removed and the pump coupled to the motor, measure the annular area between the pump shaft and the side of the stuffing box.
   This is to detect a possible "bow" in the shaft, and to ensure that the stuffing box is properly installed in the pump housing.
   With the pump uncoupled and the pump shaft supported by a temporary bearing installed in the bottom of the stuffing box, rotate the shaft and measure shaft run out.

Note: Flowserve believes that these measures will not detect shaft bow. They report there are no external measurements that can be taken to confirm a bow in the shaft. We feel the measurements should be taken complete the troubleshooting begun in RF09 and obtain all remaining possible external data prior to the final decision to replace 'B' Reactor Recirculation pump.

Vibration Issues in 2004

On March 13, 2004, Hope Creek plant personnel entering the north pipe chase heard an unusual banging noise that appeared to originate from inside containment. When the plant was subsequently shutdown, containment walk-downs revealed a number of degraded conditions inside containment, primarily on the RHR return lines that connect to the recirculation piping main loops. The degraded conditions were thought to have resulted from vibration of the recirculation and RHR piping during operation.

As part of the investigation, in Spring 2004 PSEG Nuclear monitored vibration of the recirculation and RHR piping inside containment, using specially installed test equipment, as Hope Creek ascended in power following the March 2004 outage. Key results from this monitoring are as follows:

- The recirculation and RHR piping vibration inside containment occurs as a result of pressure pulsations generated by the rotation of the recirculation pumps. These are variable speed pumps, and as the pump speeds vary, the frequency of the resulting pressure fluctuations and vibrations also vary. There was no evidence of any other driving force for the vibrations seen during the Spring 2004 vibration measurements.

- Vibration levels observed during the Spring 2004 testing were well below the maximum allowed vibration levels. Further, the vibration observed in Spring 2004 is comparable in magnitude to the vibration measured during startup testing in 1986 and during special testing performed in 1991.

Based on these findings, the root cause of the vibration itself is fully understood; it results from the rotation of the recirculation pumps.

The effect of this vibration has been to cause degradation of components in the RHR piping inside containment; specifically, hardware connected to certain RHR valves.

The common cause of the current and past degradation observed at the plant results from equipment being subjected to pump-induced pressure pulsations at frequencies at or near equipment structural resonance's. This has resulted in vibratory loads on the equipment that over time cause the equipment to degrade due to high cycle wear, fretting or fatigue.

Analysis of Degraded Conditions

The effect of this vibration has been to cause degradation of components in the RHR piping inside containment; specifically, hardware connected to certain RHR valves. A description of each degraded condition follows:

Detachment of the F050A actuator

The actuator was subject to pipe accelerations due to pump-induced pressure fluctuations that caused the actuator cylinder to sway back and forth. This in turn caused relative motion of the male and female threads where they contact each other in the threaded joint connecting the cylinder to its casting support, leading to thread wear and increased clearances. As the clearances increased, the magnitude of the resulting relative motion increased, leading to accelerated wear. This continued until the thread clearances opened up to the point where there was little overlap in the threaded joint. As this occurred retention force for this joint shifted to the cap screw installed for anti-rotation. The tip of the cap screw gradually wore off due to continue relative motion, permitting the cylinder to slide down the casting until it finally fell off. This actuation cylinder will be modified in RF12 to strengthen the cylinder.

Detachment of the F060B valve hand wheel
Vibration occurring at the hand wheel resulted in wear on the hub-bearing surface. The loss of metal at the hub eventually resulted in the retaining ring losing its grasp on the hub, at which point the retaining ring fell off. With the retaining ring gone, the hand wheel was free to fall off the hub and did so after becoming cocked on the hub (and causing wear) for a period of time. This hand wheel will be removed during operation.

Limit switch failures of the F060A and F060B valves
The F060A and F060B limit switch failures are likely caused by motion of the stem protector assembly that leads to repeated contact and fatigue of the limit switch fingers. The stem protector assembly likely has a natural frequency response in the range of expected vane passing frequencies, which results in amplification of the accelerations acting at the RHR pipe at this location. These limit switches have been redesigned and will be replaced in RF12 with a more robust design.

Vibration Monitoring for Extended Power Up-rate Project
A Design Change has been produced as a result of the PSEG Extended Power Up-rate Project, in conjunction with General Electric (GE), Task Report T-0318, and ongoing EPU industry issues, defining systems requiring Flow Induced Vibration (FIV) monitoring due to the implementation of the Extended Power Up-Rate.

Piping system monitoring will occur inside the drywell (room 4220), Turbine Building steam tunnel elevation 123' (room 1405/3491), and in Feedwater Heater Room 1504 at elevation 137'. The following piping systems will be monitored for FIV; Main Steam (drywell and Turbine Building), Main Steam Relief Valve Discharge Piping ("J" & "P " valves discharge), RCIC Steam Supply (inside drywell), Feedwater (drywell and Turbine Building), Extraction Steam, Recirculation system and RHR connections inside drywell. Forty-eight accelerometers at nineteen locations will be monitored in the drywell. Twenty-four accelerometers at ten locations, and twenty strain gages at eight locations will be monitored in the Turbine Building. The drywell instrumentation will be connected through drywell electrical penetration 1BW202, to a cabinet mounted near the "B" side drywell access hatch in the Reactor Building at elevation 102'.

Baseline data for each of these locations will be taken during startup following RF12. This data will be analyzed and compared to acceptance criteria specified in the test procedure.

The acceptance criteria will be based on ASME OM-S/G-1994, Standards and Guides for Operation and Maintenance of Nuclear Power Plants, Part 3, 1994 Edition, "Requirements for Preoperational and Initial Start-Up Vibration Testing of Nuclear Power Plant Piping Systems."

This test will verify that vibration in the Recirculation System piping is presently within design limits and provide a baseline for comparison to conditions that will exist after power is increased after the power Up-Rate Project is completed.

In Service Inspection of "B" Recirculation Piping Welds

Hope Creek conducts in-service inspection (ISI) nondestructive examinations (NDE) of its "B" Loop Recirculation System piping in accordance with plant Technical Specifications and the collaborative requirements of ASME B&PV Code Section XI and Generic Letter 88-01 for IGSCC. Prior to RFO12 Hope Creek performed Code required NDE (ultrasonic testing, liquid penetrant testing, radiography and visual examinations) of piping welds in accordance with Subsections IWB and IWF Articles IWB-2412 and IWF-2410. Beginning with RFO12, Hope Creek has started implementing risk informed in-service inspection of Class 1 and 2 piping welds in accordance with its NRC submitted relief request. PSEG Nuclear is currently awaiting final approval from the NRC of its request. Discussions with Licensing have indicated that the NRC is expected to approve mid-November 2004.

During RFO12 Hope Creek will be performing one automated UT exam and three manual UT exams of the of B Loop Recirculation System using Performance Demonstration Initiative (PDI) demonstrated and qualified equipment, procedures and personnel per ASME XI Appendix VIII requirements. In RFO12, Hope Creek has elected to implement the requirements of BWRVIP-75, BWR Vessel and Internals Project, Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules as approved by the NRC. Application of this initiative was planned to be coincidental with the implementation of RI-ISI.

PSEG Nuclear has previously conducted ultrasonic and liquid penetrant examination of several piping welds and welded attachments and observed no unacceptable indications to date. Completed visual examinations have also shown no unacceptable conditions to date.

To date Hope Creek has conducted automated ultrasonic testing of all six B Loop Recirculation System piping welds deemed susceptible to IGSCC per Hope Creek Technical Specifications and Generic Letter 88-01 requirements. No unacceptable indications have been noted to date. These welds are limited to the Inlet and Outlet Nozzle to Safe Ends configurations. These locations have also received the Mechanical Stress Improvement Process (MSIP) during RFO7 (N2) and RFO11 (N1) to mitigate potential IGSCC growth and initiation. During RFO12 the N1A and N1B Outlet Nozzles will receive an automated UT exam to assess their condition after one run cycle per regulatory commitments. Many of these exams have been conducted every second outage since RFO2.

Hope Creek has also conducted ultrasonic testing and liquid penetrant testing of approximately 35% of its Loop B piping welds since the station went into service in 1987. Approximately 24% of the remaining components have only received a PT exam since the station went into service in 1987. Many of these PT "only" exams were conducted to meet augmented examination requirements imposed by a PSEG Engineering directive issued during the 2nd ten-year inspection interval. During this 2nd ten-year inspection interval the B Loop has completed UT of approximately 23% of this loop's piping welds. After completion of RFO12, Hope Creek would have completed 28% of this loop's piping welds and 100% of the nozzle to safe-end welds.

The 2nd ten-year in-service inspection interval is scheduled to conclude with breaker closure of RFO14 (Fall 2007). Hope Creek does not currently have any ISI NDE piping exams scheduled to the B Loop Recirculation System during RFO13 or RFO14. The N2D and N2E reactor vessel nozzle to shell welds and inner radii areas are to be completed during RFO13 as well as the reactor vessel's longitudinal welds.

History of Vibration-Induced Cracking in Hope Creek Recirculation Small Bore Piping

Date	Incident	Resolution
February 1987	**Recirculation Loop A Discharge Valve V002** – Cracked seat drain connection for valves V017, V018	Removed and replaced seat drain assembly in shortened configuration.
September 1987	**Recirculation Loop B Suction Elbow** – Cracked two outer elbow tap connections for valves V653, V654 (isometric 1-P-BB-320) and valves V656, V655 (Isometric 1-P-BB-328) **Recirculation Loop A Discharge Valve (V002)** – Cracked the gland vent valve connection for Valves V034, V035 (Isometric 1-P-BB-272)	Removed all the double isolation valve assemblies from all the elbow taps and from the valve stems and glands of the recirculation isolation valves on recirculation loop A and B. The seat drain connections were left in place on the recirculation isolation valves (see DCR-4-HC-00143). Performed vibration testing during plant restart.
November 1988	**Recirculation Loop B Discharge Valve (V005)** – Cracked seat drain valve connection for valves V028, V029 (Isometric 1-P-BB-272)	Removed all the double isolation valve assemblies from the recirculation isolation valve seat drains. (See DCR 4-HM-0513)
December 1989	**Recirculation Loop B Suction Elbow** – Cracked the outer elbow tap connection (Isometric 1-P-BB-328). Previously cracked in September 1987.	Added tie back supports to the outer elbow tap connections (see DCP 4EC-3187). Added vibration monitoring instrumentation (see DCP 4EC-3186). Performed vibration testing during plant restart.
October 2001	**Recirculation Loop A Suction Elbow** – Cracked the outer elbow tap connection on Isometric 1-P-BB-321.	Removed the vibration monitoring instrumentation and associated hardware that had been installed earlier in the plant life and left in place (see DCP 80035590). The added mass due to this hardware caused the pipe section to have a natural frequency near the excitation frequency.

Date	Incident	Resolution