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HOPE CREEK GENERATING STATION
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This letter forwards PSEG Nuclear (PSEG) responses to Nuclear Regulatory Commission (NRC) questions regarding the 'B' Reactor Recirculation Pump vibration and the High Pressure Coolant Injection (HPCI) turbine exhaust line.

The information is provided in sequential order so that the historical evolution of the questions and concerns can be reviewed in perspective. As such, some information has been superceded by the later documents.

Enclosure 1 is a tabulation of the NRC questions and PSEG responses provided prior to the December 17, 2004 technical meeting conducted at NRC headquarters, Rockville, Maryland.

Enclosure 2 is a tabulation of NRC action items and PSEG responses subsequent to the December 17, 2004 meeting.

Enclosure 3 is PSEG's response to NRC questions identified during a conference call on December 23, 2004 between members of NRC Staff and PSEG Management (referred to as the December 24 questions).

Enclosure 4 provides a listing of the remaining documents previously provided to the NRC with regards to the 'B' Reactor Recirculation Pump vibration and the High Pressure Coolant Injection (HPCI) turbine exhaust line inspection activities.

You will note that PSEG has determined that the bulk of the material can be placed on the docket. However, a few of the documents do contain proprietary disclaimers requiring that we contact the providers in order to determine document status. If the document providers believe that the material should be withheld an affidavit to that end will be provided.

If you have any questions or require additional information, please contact Mr. Brian Thomas at (856) 339-2022.

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Enclosures

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1) **Regarding the S&L conclusion on operating for another cycle, the S&L report does not currently make a conclusion. The report conclusion should address the probability or likelihood of the shaft cracking leading to shaft failure over the next operating cycle.**

   Response:

   S&L concluded that a change out of the Hope Creek 'B' Reactor Recirculation pump in RF13 is acceptable because it is improbable that there will be a shaft cracking failure over the next two operating cycles. Both the vibration levels and the time in service for the pump are comparable to other reactor recirculation pumps in the industry. The 'B' Reactor Recirculation pump vibration levels also have been stable for the last two operating cycles; therefore, there is no reason to believe that the current level of vibration is causing pump degradation.

   The assumption that the Hope Creek reactor recirculation pump shafts have thermally induced cracking is based on the General Electric (GE) documentation (SIL 459) that all the Byron-Jackson (now Flowserve) reactor recirculation pump shafts that have been inspected have had thermal stress cracks. Therefore, while the Hope Creek reactor recirculation pumps can be expected to have thermal axial stress shaft cracks, no data indicates that the thermal stress cracks will propagate to the point of failure without additional mechanical loads. There is no data to indicate that the Hope Creek reactor recirculation pumps are being subjected to the mechanical loads that would cause the thermal stress cracks to propagate into circumferential cracks and ultimately, shaft failure. See response to Question 3 for further details.

2) **Provide technical basis for the 80,000 hours given in SIL 459.**

   Response:

   The GE SIL 459 recommends several actions for stations to take to improve the monitoring of their Byron-Jackson (now Flowserve) reactor recirculation pumps. Those actions include vibration monitoring and an inspection of the reactor recirculation pump after 80,000 hours of operations or approximately 10 years. Neither GE nor Flowserve have a documented basis for this pump inspection frequency. The 80,000-hour inspection interval was developed in 1987, less than 18 months after the first report of reactor recirculation pump shaft cracking. Both GE and Flowserve believe that this inspection frequency was developed based on the initial theories of the cause of the shaft cracking, and shaft crack propagation projections based on the very limited empirical data available at the time. After SIL 459 was issued, Flowserve performed several years of extensive testing and analysis into the shaft cracking issue. Their final conclusions on the thermal cracking propagation projections and the mechanical loads required to transition the crack into a circumferential crack were different than the initial theories and projections.

The axial thermal stress cracks are by themselves not detrimental to the operation or reliability of the reactor recirculation pump. However, over time and with increased mechanical loading, the axial thermal cracks transition into circumferential cracks, which can lead to shaft failure. The time between the cracks departure from the expected thermal crack propagation line to the ultimate shaft failure is calculated to be a period of 1-2 years with the higher mechanical loading. (See figure 3.7 of reference 3) There is no empirical data to validate this calculated time period. A survey was performed of stations in the Boiling Water Reactor Owners Group (BWROG), and only one station was found that has performed a shaft inspection since 1987. Due to the high cost of removing a reactor recirculation pump and the high associated radiation doses, the industry practice has been to replace the reactor recirculation pumps with a new pump when either pump performance or life cycle management concerns dictate pump replacement.

3) **Is there a fatigue growth calculation for the postulated cracks in the shaft?**

Response:

Crack propagation calculations exist for the thermal stress induced shaft cracks. These calculations have been verified by both physical testing at power stations in Japan and by the accumulation of empirical data from reactor recirculation pumps that have been refurbished. They indicate that thermal stress cracks are not expected to propagate to the point of shaft failure.

Crack propagation calculations also exist for the circumferential cracks that develop in higher mechanical load cases. These calculations have resulted in a graph, which correlates the mechanical load on the shaft to the minimum crack depth necessary to propagate the crack into circumferential cracks and ultimately shaft failure. (See figure 3.7 of reference 3) They indicate that for pumps operating close to their design point, the mechanical loads are low enough that the highest expected crack depth for thermal stress cracks will not propagate into circumferential cracks. The Hope Creek Reactor Recirculation pumps operate in a band of 44,000 - 45,000 gpm with a best efficiency point of

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39,000 gpm. This represents a 15% deviation from the best efficiency point and indicates a nominal loading increase on the Hope Creek reactor recirculation pumps.

4) **Status of all SIL 459 Recommended actions. Discuss RACs temperature and flow.**

SIL 459 12/15/87 (Reference 5)

Recommended Action:

(1) Consider installing shaft vibration probes.
Status: Both 'A' and 'B' Reactor Recirculation pumps have two proximity probes (X and Y directions) located on the pump shaft/coupling. The vibration channels, i.e., H1BB – 1BBVT7910A/B1/2, indicate in the control room and contain alarms. (See Reference 12)

(2) Consider monitoring RACs effluent.
Status: The RACs system contains radiation monitor H1SP -1SPRE-2534. (See Reference 13)

(3) Inspect pumps with greater than 80,000 hours of operation.
Status: Hope Creek station does not perform periodic reactor recirculation pump inspections. (See References 9 and 10)

(4) Prepare inspection plan to include the following: (Only if pump inspected)
- Method to examine shaft.
- Criteria for return to service
- Repair methods
- Plans for parts replacement

Status: Recirculation pumps not inspected.

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(5) Report the results of pump inspections to GE. (Only if pump inspected)
Status: Recirculation pumps not inspected.

SIL 459S1 03/23/90 (Reference 6)

Recommended Action:

None

SIL 459S2 10/21/91 (Reference 7)

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Recommended Action:

(1) Consider installing shaft vibration probes - *Repeat from original.*

(2) Consider monitoring RACs effluent. - *Repeat from original.*

(3) Reduce seal purge flow.
Status: Reactor Recirculation pump mechanical seal purge system flow reduced to 1.5-2.5 gpm. (See Reference 11)

(4) Additional recommendations:
- Improve shaft surface condition
  Status: This will be accomplished when the reactor recirculation pumps are upgraded to the 4th Generation reactor recirculation pumps.
- Improve balance and alignment
  Status: The pump alignment was improved in RF09. (WO 60004748) Pump balance correction was attempted, but there was on imbalance to correct. (WO 60004748, 60018593, 60014335)
- Reduced shaft vibration amplitudes.
  Status: Significant troubleshooting has been performed to improve 'B' Reactor Recirculation pump vibration levels. (See Reference 10)
- Reduce operational transient frequency.
  Status: Operators continue to operate the plant in a manner consistent with plant safety, and transition the plant only when required.

(5) Replace parts with upgraded parts.
Status: The station has purchased two 4th Generation Reactor Recirculation pumps, which are the vendor recommended upgrade to resolve all shaft cracking concerns.

<u>SIL 459S3 08/31/93</u> (Reference 8)

This SIL describes shaft cracking in Sulzer-Bingham pumps, which is not applicable to Hope Creek Station.

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5) **Does GE concur with the S&L statement (page 15 of report) that we meet SIL 459?**

Response:

GE does not consider any of the recommendations in SIL 459 or its supplements to be requirements for which the utility must comply. They do not wish to review utility actions to determine compliance. The recommendations they provided are suggested actions to improve component reliability. If the recommended actions were required for the safe operation of the component the actions would be issued in a Potential Reportable Condition (PRC) report under the guidance of 10CFR21.

6) **Does the shaft bow increase the chance of a shaft crack?**

Response:

The shaft bow does not increase the chance of the initiation of a shaft crack. The shaft cracks are initiated by thermal (not mechanical) stresses. The bow does contribute to the vibration level of the pump.

GE and Flowserve found in their investigations that the amount of shaft mechanical loading being experienced by any particular pump is difficult to quantify. They have been unable to develop a methodology to quantify shaft mechanical loading. The mechanical loading is a function of the forces on the shaft, which include shaft torque, radial impeller thrust, pump vibrations, and residual loads from initial pump installation tolerances. Of these forces the radial impeller thrust is considered the largest. None of the published shaft cracking technical documents, failure analyses, shaft cracking testing, or industry operating experience has identified elevated vibrations as a significant contributor. The exact cause of the high mechanical loading that lead to the circumferential shaft cracks found in the Grand Gulf reactor recirculation pumps has not been determined; however, elevated vibration were not a factor since the Grand Gulf reactor recirculation pump vibration levels are below the industry average.

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7) **Are the vibrations in 'B' Reactor Recirculation pump (due to the bow) related to the shaft cracking?**

Response:

No, the shaft cracking is initiated due to temperature gradients in the shaft that occur during system operation. The bow likely occurred due to the relaxation of stress imparted into the shaft during initial fabrication.

8) **Will the vibrations make the shaft cracking worse?**

Response:

No, not at their current levels. Also, see the answer to Question (6)

9) **Has the risk significance of the recirculation pump (shaft cracking) been assessed and has the PRA group evaluated it?**

Response:

The PRA Group has evaluated the reactor recirculation pump shaft cracking issue. Reactor recirculation pump shaft cracking is not included in the PRA model. The PRA group analyzed the risk significance of reactor recirculation pump shaft cracking and found it to be small. The PRA group assessment is as follows:

Input Data:	Number of cracked shafts in the industry	-	4
	Number of pump operating years in the industry	-	1778

Notes:

(1) For the purposes of the shaft cracking evaluation, the industry is defined as the 77 reactor recirculation pumps installed in the 35 plants that are members of the BWROG.

(2) The response to Question 6 concluded that vibration levels are not a significant contributor to the propagation of shaft cracking; therefore, the elevated vibration level of the 'B' Reactor Recirculation pump was not included in this evaluation.

(3) For conservatism, the number of pump operating years was reduced to 25% of the calculated value given above.

A conservative approach is to assume that there were 4 failures in 444 pump years. This will give an estimate of 9.0E-3/year. (i.e., 4/444)

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The failure experiences indicate that if a crack is developed while in operation, manual shutdown is the most likely outcome. Using a non-informative prior, the likelihood of the consequences other than manual trip given the shaft failure is about 0.25. It is judged that a turbine (or reactor) trip or a small LOCA is equally likely given the shaft failure and manual trip is not initiated.

To be conservative, the risk analysis assumes the following:

1. Annual shaft failure likelihood is 9.0E-3.

2. Given the shaft failure, there is a 0.125 chance a small LOCA is developed and a 0.125 chance a turbine (or reactor) trip event will occur.

Therefore, the additional annual risk (CDF) of Hope Creek operation with one recirculation pump is the summation of the following:

1. 9.0E-3*0.75* 1.44E-6 = 9.7E-9
2. 9.0E-3*0.125*1.6E-6 = 1.8E-9
3. 9.0E-3*0.125*1.36E-4 = 1.5E-7

Sum = 1.6E-7

The additional risk of Hope Creek station operation with the vibration is about 1.6E-7/year. This is judged to be small.

The above analysis is sensitive to the assumption of shaft failure likelihood. If the shaft failure likelihood is to be increased by a factor of 10, the estimated CDF is increased to 1.6E-6/year.

The analysis is also sensitive to the assumption of the consequence given the shaft failure. If the shaft failure is assumed to cause a small LOCA, the estimated CDF is increased to 1.1E-6/year.

These two sensitivity cases are judged to represent the upper bound of the estimated risk. If the benefits of significant increase of monitoring devices and high operator awareness are factored into the sensitivity cases, most likely the CDF increase is going to be limited to the high E-7 range.

In conclusion, the CDF increase is in the low E-7/year. The distribution is likely in the range from low to high E-7/year. The risk increase is considered small.

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10)What is the risk of shaft failure with the bow and cracked shaft?

Response:

The risk for a shaft failure for the 'B' Reactor Recirculation pump is no greater than any other reactor recirculation pump with the same service life.

The shaft bow increases the pump's vibration levels. Vibrations do increase the mechanical loading on the shaft, but the amount is insignificant. The shaft cracks, which are suspected to be in the Hope Creek reactor recirculation pumps, are axial thermal cracks. Flowserve analysis has determined that axial thermal cracks are not detrimental to the operation or reliability of the reactor recirculation pump without additional elevated mechanical loading. There is a large database of industry experience of reactor recirculation pumps operating without shaft cracking failures for a significant amount of time beyond the amount of service time that 'B' Reactor Recirculation pump will have by the end of Operating Cycle 13.

11)What is the plant's response to a rapid shaft crack (failure of pump shaft)?

Response:

Reactor Recirculation Pump Shaft Break is described in the Hope Creek UFSAR section 15.3.4.

A rapid shaft failure could result in an automatic trip of the main turbine with resultant reactor scram due to the very rapid decrease in core flow and water level swell in the reactor.

In the event a failure of the reactor recirculation pump shaft does not result in a high reactor level trip of the reactor, the operators would remove the pump from service. Based on the nature of the failure this may be accomplished by varying methods.

If vibration levels trend up significantly prior to the failure, plant staff will remove the pump from service based on prescribed procedural limits. (HC.OP-AR.ZZ-0008(Q)) This limit is currently 21 mils.

Additionally, plant staff would enter the procedure for a tripped reactor recirculation pump should a scram not occur based on the observation of loss of the associated jet pump flow without a corresponding trip of the

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Recirculation Pump Trip Breakers or Motor Generator Set. Similar abnormal operating procedures would be entered due the negative reactivity insertion associated with the loss of the core flow and unanticipated rise in reactor level.

12) Are vibration levels indicated and alarmed?

Response:

Radial vibration levels are detected on both reactor recirculation pumps by two proximity probes (X and Y directions) located on the pump shaft/coupling. The radial vibration levels are monitored in the control room via H1BB –1BBVT-7910A/B1/2. Axial vibration levels are detected on both reactor recirculation pumps by a velocity meter located on the reactor recirculation pump motor. The axial vibration levels are monitored in the control room via H1BB –1BBVT-7910A/B4. Increases in either vibration level are detected by digital points D5351 and D5352, which provide a visual and audible alarm to the operators via overhead alarm (OHA) C1-E4 "Reactor Recirc Pump Vib Hi." The setpoint for radial vibration is 11 mils and the setpoint for axial vibration is 7 mils. In the event of an alarm operators receive guidance by Operations Procedure HC.OP-AR.ZZ-0008(Q) which gives direction to lower pump speed to lower vibration levels. If the vibration levels cannot be lowered, the pump is removed from service at 21 mils of radial vibration, or 11 mils of axial vibration.

During RF12, additional vibration instrumentation is being added to 'B' Reactor Recirculation pump motor via DCP 80062466. The new instrumentation includes five accelerometers. Three accelerometers (X, Y and Z directions) will be installed close to the upper motor bearing, and two accelerometers (X and Y directions) will be installed close to the lower motor bearing. This new instrumentation is for component trending purposes and is not alarmed in the control room.

13) Can you reliably detect the initiation and growth of a crack with our current installed instrumentation?

Response:

The growth of the crack into a circumferential crack can be seen by two methods. First, when the crack departs from the thermal crack propagation line, the 2X vibration peaks will rise and the phase angle will shift. For this reason vibration data is collected monthly. Data is downloaded monthly into the Vibration Data Acquisition system program

(ADRE) (MP# HC650050), and evaluated for any pump phase angle changes, any sudden increases in 2X vibration levels, and the condition of the vibration orbital plots for indications of shaft cracking. Flowserve has developed analytical predictions of the crack growth of a circumferential crack. The period of time between the cracks' departure from the thermal axial crack propagation line and shaft failure is 1-2 years. This should provide sufficient opportunity of the vibration trending to detect the transition of the crack.

In the event that the vibration trending does not detect the transition of the shaft crack into a circumferential crack, the reactor recirculation pump vibration levels are continuously monitored and alarmed in the control room. There is limited industry experience on actual cracked shafts to determine the amount of reaction time available to the operating crews. In the case of Grand Gulf in 1989, they received a reactor recirculation pump vibration alarm on May 11th, and performed a controlled shutdown of the plant on May 15th. There were similar results at Sequoia (Westinghouse PWR), which had a cracked shaft in 2002. Upon initial pump start after a refueling outage, the pump vibrations were immediately high. The station analyzed the condition for several hours with the pump in service prior to securing the pump. From these two examples, the only industry experience available indicates that the operating crews will have sufficient time to react and perform a controlled plant shutdown if required.

14)Has any other plant demonstrated the ability to detect a rapid crack?

Response:

Yes, Grand Gulf had a cracked shaft in 1989. See Reference 12. While raising reactor recirculation flow, operators observed a rise in pump vibration level to 17 mils. They continued the flow increase, and vibration levels rose to 32 mils, and they received the reactor recirculation pump high vibration alarm. (setpoint 20 mils) The operators responded by lowering reactor recirculation system flow, and lowering the pump speed. Reactor recirculation pump vibration levels returned to normal. The station remained in this condition for four days while the condition was analyzed. After four days, a controlled plant shutdown was performed.

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15)How much time do the operators have to respond to a recognized pump shaft rapid crack?

Response:

The response to a failed shaft is described above in Question 11 and 13. Hope Creek UFSAR section 15.3.4 analyzed the condition, modeled as an instantaneous failure. Any slower developing failure that increases the vibration level of the pump would result in a reactor recirculation pump alarm (OHA C1-E4). The alarm response, HC.OP-AR.ZZ-0008(Q), directs the operators to lower pump speed or remove the pump from service in accordance with prescribed vibration limits. (21 mils for radial vibrations and 11 mils for axial vibrations) This is not a time-based response. The design basis failure of a recirculation pump shaft would result in an automatic trip of the main turbine on high reactor water level. Reactor water level would be recovered normally with the reactor feed pumps.

16)If the shaft where to fail what are the consequences (damage to recirculation piping, seal failure, etc.)?

Response:

If a thermal axial crack in the reactor shaft were to transition into a circumferential crack, industry experience indicates the operating crews will be able to perform a controlled shutdown of the pump and plant and there would be no consequences. In the event that the shaft was to suddenly shear while in service, no reactor recirculation piping damage is expected. A qualitative review of the reactor recirculation pump indicates that upon shaft shear, the pump impeller would first drive upward due to normal in service upward thrust. This should not increase the normal upward thrust on the motor thrust bearing because there is no force to increase that upward thrust. The impeller would then settle down to the bottom of the pump casing where it is not expected to limit any reactor recirculation loop flow, nor damage the pump casing. The pump shaft will continue to rotate until the operators trip the pump. Once the shaft has sheared, there will no longer be a bearing to restrain the shaft radial movement. The shaft can be expected to encounter the sides of the casing in the thermal mixing region. No casing penetration is expected, but mechanical seal leakage is very possible.

This accident was evaluated in the Hope Creek UFSAR section 15.3.4. The breaking of the shaft of a reactor recirculation pump is considered a design basis accident (DBA). It has been evaluated as a very mild accident in relation to other DBAs, such as a loss-of-coolant accident (LOCA). The analysis was been conducted with consideration to a single or double loop operation. The postulated event is bounded by the more limiting case of a reactor recirculation pump seizure.

A postulated instantaneous break of the pump motor shaft of one reactor recirculation pump will cause the core flow to decrease rapidly, resulting in water level swell in the reactor vessel. When the vessel water level reaches the high water level setpoint, L8, main turbine trip and feedwater pump trip will be initiated. Subsequently, reactor scram and the remaining recirculation pump trip (RPT) will be initiated due to the turbine trip. Eventually, the vessel water level will be controlled by high pressure coolant injection (HPCI) and reactor core isolation cooling (RCIC) flow.

The severity of this pump shaft break is bounded by the pump shaft seizure event, which is evaluated separately. In either of the two events, the recirculation drive flow of the affected loop decreases rapidly. In the case of the pump shaft seizure event, the loop flow decreases faster than the normal flow coast down, as a result of the large hydraulic resistance introduced by the stopped rotor. For the pump shaft break event, the hydraulic resistance caused by the broken pump shaft is less than that of the stopped rotor for the pump shaft seizure event. Therefore, the core flow decrease following a pump shaft break effect is slower than the pump shaft seizure event. Thus, it can be concluded that the potential effects of the hypothetical pump shaft break event are bounded by the effects of the pump shaft seizure event.

17) Is the end of useful life modeled for the pump?

Response:

No, there is no specific model for Byron-Jackson (now Flowserve) reactor recirculation pumps to monitor the pump performance and to determine the amount of useful life remaining. There are many indications that a pump is reaching the end of its useful life. The pump performance could degrade due to wear of the wear rings, or the pump vibration levels could rise due to wear of the bearings. In the case of Byron-Jackson reactor recirculation pumps, there have been no reports of pump performance degradation, and no indications of wear in the wear rings of pumps being refurbished. There have been indications of wear in the hydraulic bearing in pumps that were being refurbished. Hydraulic bearing wear of a pump in service could be seen by vibration levels slowing going higher, which is not the case in either Hope Creek reactor recirculation pump.

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18)The pumps have cracks. Has this been evaluated as a non-conformance and what are the conclusions? (See report pg. 21)

Response:

No cracks in the Hope Creek reactor recirculation pump shafts have ever been physically identified. Industry experience collected by the pump vendor (Flowserve) indicates that reactor recirculation pump shafts develop thermal stress cracking after as little as 500 hours of operation. Since the Flowserve has identified thermal stress cracks on all the non-4th Generation reactor recirculation pumps that is has refurbished, it is possible that both 'A' and 'B' Reactor Recirculation pumps, which are 1st Generation reactor recirculation pumps, have thermal stress cracks. The thermal stress cracks have never been evaluated as a non-conformance because they are located in an inaccessible portion of the shaft, which can only be identified by pump removal. Neither 'A' nor 'B' Reactor Recirculation pumps have ever been removed for inspection. However, the thermal axial shaft cracking condition has been well evaluated by Flowserve, and it does not affect the operation or the reliability of the reactor recirculation pumps.

19)If thermal stress, not bowing, is the basis for the shaft cracking, why does S&L recommend only replacing 'B' in RF13? Why didn't S&L recommend the replacement of both A and B shafts?

Response:

Replacing the 'B' Reactor Recirculation pump first is recommended because it has experienced more seal failures and has higher vibrations that the 'A' Reactor Recirculation pump. Replacement of the 'A' Reactor Recirculation pump is recommended for RF14 unless there is indications of pump degradation before that. Based on U.S. industry experience, reactor recirculation pump shaft failures due to thermal shaft cracking have not occurred. The number of operating hours that the 'A' pump will have experienced by RF14 is not atypical for reactor recirculation pumps in U.S. plants. Therefore, shaft failures are not expected to occur between now and RF14.

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20) Provide a description of the new vibration monitoring program that will be implemented during the next cycle.

Response:

The original vibration program will remain in place for both the 'A' and 'B' Reactor Recirculation pumps. This program includes two proximity probes (X and Y directions) located on the pump shaft/coupling. These probes provide radial vibration data, which is used for engineering trending purposes, and is displayed and alarmed in the control room for continuous operations monitoring. The program also includes one velocity meter located on the top of the motor. It provides axial vibration data, which is used for engineering trending purposes, and is displayed and alarmed in the control room for continuous operations monitoring.

During RF12 additional vibration instrumentation is being installed on the 'B' Reactor Recirculation pump motor only. (DCP 80062466) This additional instrumentation includes two accelerometers (X and Y directions) located low on the motor housing; and three accelerometers (X, Y, and Z directions) located on the top of the upper motor bearing. These detectors will be read at a data collection cabinet outside the containment, but not in the control room. The data will be periodically downloaded to the Stations vibration program for engineering trending purposes.

<u>Description of Drywell Piping Vibration Monitoring System (DCP 80062466)</u>

Vibration monitoring instrumentation is being installed on various piping systems throughout Hope Creek. This instrumentation is required for several reasons:

1) To assess any increases in flow-induced piping vibration that might occur as a result of future power uprate; and
2) To implement Independent Assessment Team recommendations for assessing the magnitude of drywell piping vibrations that may be occurring due to reactor recirculation pump rotational vibration or pump vane pass frequency excitation of those systems. Monitoring will be conducted during plant startup and during the operating cycle.

In the Drywell, vibration instrumentation (100 accelerometers) are being installed to monitor approximately 40 locations. Systems to be monitored will include the recirculation system, RHR, main steam, and feedwater and selected attached components and piping. The specific locations are based on recommendations developed by the Power Uprate project and also the Reactor Recirc Vibration Independent Assessment Team. The drywell instruments will be connected through penetrations to two local data acquisition systems located in rooms 4303 and 4310 adjacent to the drywell.

In the Turbine Building and steam tunnel, vibration instrumentation (24 accelerometers and 20 strain gages) is being installed to monitor approximately 18 locations. Systems to be monitored will include main steam, feedwater, and extraction steam in the Turbine Building and steam tunnel. These instruments will also be connected to one local data acquisition system located in Turbine Building Room 4101.

21) Were any safety related components rendered inoperable due to the vibration?

Response:

No. The safety-related components are discussed below:

1BC-HV-F050A, testable check valve in RHR A return line.

This valve (and similar valve 1BC-HV-F050B in RHR B return line) prevents back flow from the RR system in conjunction with containment isolation valves 1BC-HV-F015A/B.

Component degradation to this valve has been limited to external, non-pressure boundary elements, which are utilized only during valve seat testing, conducted during unit outages. These initially included detachment of the air actuator cylinder, but more recently the apparent missing linkage key and looseness (but no degradation) of the top mounted limit switch power supply. Degradation or the loss of these elements would not allow for testing of the valve during scheduled outage testing. Loss of the power supply and or linkage key would limit the ability of the operator to confirm valve position, which is passively closed during normal RR pressure and open upon RHR initiation.

Hence, the noted conditions would not by themselves be considered as an inoperable condition for the valve to function as designed.

1BC-HV-F060A/B and 1BC-HV-F077, manual gate valves

Valves 1BC-HV-F060A/B are locked open and used to isolate testable check valves F050A/B for maintenance or test. Valve 1BC-HV-F077 is locked open and used to isolate valve F009 for maintenance or test.

Component degradation has been limited to external, non-pressure boundary elements. These components are utilized only for verification that the valves are open (limit switch indication hardware and cables) or to manually put the valves to a closed position (hand wheel, gear box cover, pinion gear and yoke nut).

Hence, the noted conditions would not by themselves be considered as an inoperable condition for the valves to function passively in the open position as intended.

22)The cause of step change in pump vibration at RF11 is not known. How can the statement its okay be made without knowing the cause of the step change? (Pg. 10 of report)

Response:

The 'B' Reactor Recirculation pump vibration signature prior to the planned outage in March 2003 (on month prior to RF11) had been steady since the pump was placed in service after RF10. The overall magnitude of the vibration was steady at 7-8 mils prior to the outage and steady at 9-10 mils after the outage. The vibrations continued at this magnitude after RF11, and remained steady for all of Cycle 12. The vibration spectrum prior to the outage indicated a 1X vibration magnitude of 5 mils and a phase angle of 269°, and the 2X magnitude of 0.84 mils and a phase angle of 284°. The vibration spectrum after the outage indicated 1X vibration magnitude of 7.5 mils and a phase angle of 292°, and the 2X magnitude of 0.82 mils and a phase angle of 270°. The shift in the 5X vibration was within the normal data scatter. This change in magnitude and phase angle vibration data indicates a change in the pump coupling stack-up. During the outage, the pump was uncoupled and the vibration probes removed to facilitate the replacement of the mechanical seal. The replacement of the mechanical seal would not affect vibration levels; however, the uncoupling and re-coupling of the pump and motor may affect the vibration levels. During this process the pump hub is removed and reinstalled. Any variation in the position of the pump hub would translate into a change in vibration levels. In addition, the lower rabbit fit of the coupling spacer was oversized to allow proper alignment during RF10. The resulting rabbit fit was 4 mils oversized. In this condition, the pump can be properly coupled, but repeatability of the pump alignment was difficult. With the coupling spacer in a slightly different location, a slight coupling imbalance would affect the vibration readings. The lower rabbit fit of the 'B' Reactor Recirculation pump coupling spacer is being restored during RF12 under WO 60036037. The removal and recalibration of the vibration probes could also result in a step change in vibration signature, but the shift in vibration phase angle indicates that this is not an instrumentation only concern.

As stated in the report, the post-RF11 vibration amplitudes were similar to the pre-RF09 vibration amplitudes and the vibrations are not trending upward. Considering this evidence, the step change in vibration does not indicate pump degradation.

23)What was the affect of moving the probes and is the vibration data consistent? It appears that there are errors in the S&L graph.

Response:

The specific effect of moving the vibration probes cannot be quantified from the available data, since the balance weights were removed about the same time that the probes were moved. However, considering that the pre-RF09 and post-RF11 vibration amplitudes are similar, the effect of moving the probes does not appear to be significant.

There have been two configuration changes made to the Reactor Recirculation pump vibration instrumentation.

During RF10 (November 2001) the X and Y proximity probes were inadvertently switched. (CR 70043098) The two proximity probes are identical. The X and Y locations are arbitrary and only need to be 90° apart to perform their required functions. With the probes switched there is no change in the accuracy of the readings, but the continuity of the data trend will be challenged if the switch was not properly identified. The switch was identified immediately and the vibration data trend annotated, thus permitting proper continuity in the vibration trend.

During RF10 (November 2001) the X and Y proximity probes were moved via DCP 80036347 from the original location sensing on the lower flange of the coupling spacer to the flange of the pump hub. This was done because it was believed at the time that the OD of the lower flange of the coupling spacer was out of round and giving a false vibration reading. During RF12 (November 2004) the coupling assembly was dimensionally verified under WO 60036037 and both the OD of the lower spacer flange and the OD of the pump coupling hub flange were found to be round to within 0.001 inch. Therefore, the DCP installed in RF10 had no affect on the pump vibration trend. The vibration readings taken before and after the DCP installation are of the same accuracy. Any actual effect of moving the vibration probes cannot be quantified, since the balance weights were removed about the same time that the probes were moved. However, considering that the pre-RF09 and post-RF11 vibration amplitudes are similar, there does not appear to be an effect from moving the probes.

The S&L report was created from vibration data supplied to them from PSEG Engineering. The graph contains overall vibration data in both the X and Y directions. PSEG Engineering independently developed an almost identical graph, and confirmed that the S&L graph in the report is accurate.

24) The pump vibration levels were highest in cycle 10 and lower now. Why is the rate of vibration related components failures increasing?

Response:

The vibration levels in 'B' Reactor Recirculation pump are not related to the failed components in the recirculation system. The vibration levels in the reactor recirculation pumps are measured by proximity probes located on the pump coupling. The 'B' Reactor Recirculation pump vibration levels last cycle were 8-10 mils. The reactor recirculation pump has the following clearances:

Lower pump wear rings	50-52 mils
Upper pump wear rings	25-26 mils
Hydraulic bearing	13-15 mils
Thermal mixing region	25-26 mils

The prominent vibration peak of the reactor recirculation pumps is at 1X running speed. This is a measure of the excess energy in the pump's rotating assembly caused by inconsistencies in the alignment of the motor bearings, the stack-up of the coupling, and the bow in the shaft. Due to the pump clearances, this energy is not transmitted to the piping system.

This can also been seen in the observed vibration spectrum. The predominant frequency peak in the reactor recirculation system is 5X and 10X running frequency. This is a result of hydraulic forces from the pump's five vane impeller. The 5X and 10X running frequency vibration peaks have an insignificant contribution to 'B' Reactor Recirculation pump's vibration level.

The historical data trend of F060/F077 failures documented in engineering evaluation H-1-BB-CEE-1862 displays that increased pump vibration levels does not correlate to increased number of component failures.

25)Did S&L look at just the current (RF12) small bore ISI results or did they also look at previous data?

Response:

The S&L team reviewed the small-bore ISI results for RF12 and from each of the previous outages at Hope Creek station.

26)Vibration of Large Bore Piping. References 6.2 and 6.3. S&L report just critiques these references but does not come to any conclusion. Please provide copies of References 6.2 and 6.3.

Response:

Copies provided.

27), Is the rigid thermal restraint inducing stresses (Page 12 of report, Hope Creek pump snubber supports are less)

Response:

The Independent Assessment Of Hope Creek Reactor Recirculation System And Pump Vibration Issues dated November 12, 2004 on page 12 states:

"D. Pump Support Configuration
The Hope Creek support configuration was compared to Dresden, Quad Cities, Browns Ferry, and Clinton RR pump support configurations. This comparison is presented in Appendix C. The key conclusions are:

- The Hope Creek RR pump and motor supports are similar to other plants except that Hope Creek motor supports consist of two snubbers compared to three snubbers for the motor supports for the other plants. The 3rd motor support snubber at Hope Creek was removed during the snubber reduction project. Thus, the RR pump motor at Hope Creek is somewhat less restrained than other MARK I plants and Clinton (MARK III).

- The Hope Creek RR pump casing is restrained at the bottom by a rigid restraint that has the potential to constrain free thermal movement. Other MARK I plants do not have this rigid restraint.

  The difference in Hope Creek 'A' and 'B' pump rigid restraint configuration should be investigated to ensure that it is not the cause for the high 'B' RR pump vibrations."

PSEG has reviewed the current Hope Creek reactor recirculation pipe stress analysis. (C-0142, Revision 10, "Stress Report for Recirc. Loop B" and "C-0141, -Revision 11, "Stress Report for Recirc. Loop A and RHR (Inside Drywell)"). The stress calculations include the pipe struts and the current configuration of snubbers on the motor. The loads on the struts on both loops are significantly below allowables. We have discussed the configuration with General Electric's pipe stress analyst. The analyst states the strut is used on newer Type 4, 5, and 6 reactor designs. He further states the strut is a key part of the recirculation piping support system. A review of the Byron Jackson stress report for the RRP (VTD PN1-B31-C001-0137, Revision 2) showed that the strut load on the RRP casing was not explicitly addressed. The absence of this documentation has been entered into the PSEG corrective action program. (CR No. 70042757)

The RRP rigid restraint configuration is slightly different from the design dimensional tolerances specified in design drawings. (VTD PN1-B31-G003)-0022, Revision 7. The attachment of the restraint to the "A" RRP is 5/8" lower than the lower than the minimum vertical offset from the strut centerline as compared to its opposite end attachment to the biological shield wall. The rigid restraint on the "B" RRP is within drawing tolerance. The disposition of this discrepancy has not been located in historical records. The issue has been entered into PSEG's corrective action program. (Notification 20214905)

28)Is there displacement data for large bore piping (pages 23 and 24 of report)?

Response:

The RR Displacement Acceptance Criteria was specified and is referenced as reference 6.4 (GE Report GENE-000-0027-4832-01, Revision 1 "PSEG Nuclear LLC Hope Creek Generating Station Recirculation & RHR Piping Start-up Test Criteria" (VTD 326534)).

The dynamic test data and derived displacement data, obtained in April 2004, is reference 6.3 (Ref: Calculation HC-06-301, Revision 1, "Hope Creek Recirculation System Vibration Data Reduction" (VTD 326747). Both the testing and the acceptance criteria identified RR large bore piping locations where the piping displacement were evaluated.

29)Provide copy of reference 6.4 – S&L critiques the reference report but does not draw a conclusion.

Response:

Copy Provided

30)There is a 3% reduction in core flow; why and what are we doing? Is it leading to a pump failure?

Response:

The reduction in core flow is on the order of 3% and is not leading to pump failure. The concern of reduced total core flow is being evaluated by reactor engineering. They have identified several possible causes for the reduction in flow, and pump degradation was originally one of the possible causes.

Over time any pump could experience wear ring wear, which could reduce the efficiency of the pump. Industry experience has indicated that the reactor recirculation pump wear rings to not wear while in service. Review of the pump clearances given in the response to Question 24 confirms that pump wear ring wear is not likely. There are numerous reactor recirculation pumps in the industry, which have more service time then the Hope Creek, and they have not identified any pump performance degradation. Flowserve experience refurbishing reactor recirculation pumps has found the pump wear rings to be in like new condition. Reactor Recirculation pump degradation is no longer being considered a possible cause for the flow reduction.

Reactor Engineering continues to evaluate the exact cause of the reduced core flow, but has concluded that all of the possible causes impact only economic performance and not reactor safety performance.

'B' Reactor Recirculation Pump
NRC Questions 12/01/04

31)**With respect to the Union of Concerned Scientist response to the S&L report, does PSEG plan to respond to the UCS letter?**

Response:

No. PSEG does not intend to respond to the UCS letter.

32)**Provide copy of plan to address the recommendations in the S&L report.**

Response:

The attached Table 1 is a compilation of the independent assessment team recommendations and CAP Notification Numbers.

33)**Plan for monitoring the recirculation pump vibrations during the next cycle (operator guidance). Provide a copy of the procedure for operations in the event of a shaft crack indication. Both Hope Creek Reactor Recirculation pumps have vibration levels indicated and alarmed in the control room. In the event of an alarm the operators follow the actions in procedure HC.OP-AR.ZZ-0008 pages (Reference 4).**

Response:

See procedure HC.OP-AR.ZZ-0008(Q), supplied with the references.

'B' Reactor Recirculation Pump
NRC Questions 12/01/04

References:

1) An Advanced Design Main Coolant Pump for BWR Plants, S. Gopalakrishnan, BW/IP International Pump Division, March 1996.
2) Analytical Investigation of Thermal Cracking in Reactor Recirculating Pumps, S. Gopalakrishnan, BW/IP International Pump Division, October 1992.
3) Crack Propagation in Main Coolant Pumps, S. Gopalakrishnan, BW/IP International Pump Division.
4) Evaluation of Main Coolant Pump Shaft Cracking, EPRI, 1992.
5) GE SIL 459, dated 12/15/87.
6) GE SIL 459S1, dated 03/23/90.
7) GE SIL 459S2, dated 10/21/91.
8) GE SIL 459S3, dated 08/31/93.
9) Mark Bezilla letter dated 06/12/97, Ser# GMHC-97-021.
10) H-1-BB-MEE-1878, 'B' Recirculation Pump Vibration Analysis.
11) HC.OP-SO.BB-0002(Q), Reactor Recirculation System Operating Procedure.
12) OE 3351, Grand Gulf Shaft Crack.
13) OE 3557, Grand Gulf Update.
14) OE 3565, Grand Gulf Update.
15) P&ID M-13-1, Reactor Auxiliaries Cooling System.
16) P&ID M-43-1, Reactor Recirculation System.
17) HC.OP-AR.ZZ-0008(Q), Overhead Annunciator Window Box C1, Operations Alarm Response Procedure.

Table 1
'B' Reactor Recirculation Pump
NRC Questions 12/01/04

	Question 32 Independent Team Recommendations – PSEG Actions	Page #	Notification #
1	The Reactor Recirculation (RR) pumps speed is limited to 1510 rpm, and at this speed the maximum core flow achieved in the past was 103 million. During the last operating cycle the flow dropped to approximately 100 million. The reduction may be due to instrument changes, RR pump degradation or to jet pump fouling. If the latter is deemed a significant operational concern, it should be investigated during RF12.	4	20213970
2	The RR pump instrumentation being added is being installed per a temporary modification. An effort should be initiated to make the instrumentation a permanent installation. This would include the data acquisition and recording devices and control room interfaces that would be required for the permanent installation.	11	20214011
3	Review RR pump instrumentation at other plants, including how the data from the instrumentation is being used, to help verify that the type and amount of instrumentation being added is appropriate.	11	20214011
4	The difference in Hope Creek "A" and "B" pump rigid restraint configuration should be investigated to ensure that it is not the cause for the high "B" RR pump vibrations.	12	20214012
5	For the "B" RR pump, alignment of the coupling and checking alignment when the pump is recoupled during RF12 is recommended.	16	20214013
6	The "B" RR coupling should be checked for concentricity and squareness, and balanced. Alternately, a new duplicate coupling may be available on short notice, from another plant, for replacement during RF12. If a new coupling is purchased, it should also be checked for squareness and balance.	16	20214013
7	The Hope Creek RR pumps should be monitored closely. A rapid rise in vibration amplitude would be sufficient reason to shut the pump down immediately for an internal inspection and rotor replacement, as the window between the rise and potential shaft failure is expected to be small. (Ref. 5.24)	17	20214014

Table 1
'B' Reactor Recirculation Pump
NRC Questions 12/01/04

	Question 32 Independent Team Recommendations – PSEG Actions	Page #	Notification #
8	The "A" pump should be monitored with the "B" pump, for capacity and vibrations. A rapid rise in vibration amplitude would be sufficient reason to shut the pump down immediately for an internal inspection and rotor replacement	17	20214014
9	Considering the age and time in service of the RR pumps, the Station should be prepared to rebuild the RR pumps because of capacity degradation or rapidly increase in vibrations.	17	20214017
10	The replacement "B" and "A" pump rotor on hand should be checked for rotor balance and shaft straightness before installing in the pump casings. New couplings included in the replacement packages should be checked for concentricity, squareness, and balance.	17	20214017
11	The DCP, installation plans, access and rigging plan, and inspection of the replacement parts should be done during or as soon after RF12 for replacement of "B" and "A" pumps.	17	20214044
12	The replacement pump parts on hand do not include seal cartridges. The intent is to rebuild existing seals at the Stations, using parts furnished by Flowserve. Instead, new generation seals with SiC stationary and rotating seal rings should be purchased. This should be done soon after RF12, in anticipation of an unscheduled outage.	17	20214017
13	Both "A" and "B" RRPs have operated over 130,000 hours and are approaching a perceived end of useful life. Thus, it is recommended that the "B" RRP be upgraded during RF13 and "A" be upgraded during RF14, unless monitoring shows capacity or vibration degradation earlier. "B" RRP upgrade is recommended earlier than "A" because of the higher vibration levels.	17	20214017

Table 1
'B' Reactor Recirculation Pump
NRC Questions 12/01/04

14	More accurately estimate the time "A" and "B" pumps have operated. Collect similar data form other plants. Estimate the remaining life of the "A" and "B" pumps based on data from other plants.	17	20214017
15	The acceptance criteria for March 2004 monitoring were established by performing response spectrum analyses for frequencies up to 200 Hz. The frequency range is acceptable; however, response spectrum analyses are applicable when the piping is being shaken by the building structure. The axial forcing functions from flow-induced vibration result in a different relationship between maximum pipe stresses and displacements than forcing functions applied externally from the building structure. Therefore, analyses that simulate the axial forcing functions are more applicable for developing acceptance criteria for steady-state flow-induced vibration.	23	20214018
16	The March 2004 vibration monitoring acceptance criteria are in terms of displacement. When higher frequency harmonic excitation is monitored, as is the case with vibrations caused by vane pass frequencies, it is advisable to also establish an acceleration acceptance limits in addition to the displacement limits. This recommendation is applicable to EPU vibration monitoring.	23	20214018
17	For developing the acceptance criteria for the March 2004 monitoring, response spectrum was adjusted higher in the range of the 1X pump speed component. If the 5X component is also expected to be significant, the response spectrum should also be adjusted higher in that range. This recommendation is applicable to EPU vibration monitoring.	24	20214018
18	Vibration measurements at RR pump speeds above 1500 rpm are planned. Vibrations at these higher pump speeds could increase significantly, as evidenced by the reported "freight train effect" that occurs at pump speeds above 1510 rpm. Thus, more comprehensive monitoring of the RR and RHR piping than planned is warranted for EPU. This recommendation is applicable to EPU vibration monitoring.	26	20214018

Table 1
'B' Reactor Recirculation Pump
NRC Questions 12/01/04

19	The susceptible valve component should be included in the EPU vibration monitoring program. The most effective number of sensors required can best be determined from analytical models that provide accurate vibration response characteristics.	26	20214019
20	It is planned to determine the acoustic characteristics of the RR system. In order to benchmark the acoustic model, dynamic pressure data should be collected measured near the source of the pressure pulsations (e.g., the RR pumps) and at locations where maximum acoustic responses may occur (e.g., near closed valves) during power ascension up to the maximum speeds at which the RR pumps will be operated.	26	20214042
21	The acoustic modes predicted by the acoustic model will be strongly dependent on the speed of sound used in the analysis. Means for benchmarking the acoustic velocity used in analytical models should be investigated.	26	20214042
22	The signals from the RR pump vibration and speed sensors should be tied into the data acquisition system used for EPU vibration monitoring so they can be directly correlated to the system vibration and acoustic responses. This will provide an understanding of the interaction between the pump and system responses.	27	20214018
23	The vibration acceptance limits should be in terms of peak values (displacement or acceleration) to correlate with peak stresses. Measurements taken in terms of rms vibration cannot be reliably correlated to peak values due to the quasi-random nature of pipe vibrations.	27	20214018
24	Acceptance criteria should be developed for the monitored valve components.	27	20214018

Table 1
'B' Reactor Recirculation Pump
NRC Questions 12/01/04

25	Vibration monitoring data should be collected at predetermined pump speeds or power levels during power ascension up to the maximum speeds at which the RR pumps will be operated. Data should also be collected during the RHR shutdown cooling mode of operation. Data should also be collected at planned downpower evolutions to determine the effects of potential transient loading on RR and RHR system components.	27	20144018
26	The analytical finite element model results for the current configurations of the F060A/B and F077 valve operator assemblies have not been assessed to provide a correlation to the damage observed. This correlation should address a comparison of the observed damage, (such as gear box cover plate deformations, cover plate cap screw failure, damage to the stem extender/stem interface and internal yoke nut failure) to the analytically predicted results. .	31	20214019
27	The calculations establish that the first and second mode frequencies of the existing assembly are in the range of 94-98 HZ (F077) and 60-63 (F060A/B). Prior test data has shown that RHR branch piping has notable accelerations primarily at the 5X condition of 125 Hz. Hence the damage is likely to be associated with the modal frequencies of specific components such as the gear box cover plate. Because the primary operating pump speeds expected to be used for current operation and future EPU operation range from 1300 to 1600 RPM, the criteria for the modification should based on 150 HZ or greater.	31	20214019
28	The stated action to be taken for Operation 0150 is to include sufficient post mod testing to ensure goals are met. At this time what is a "sufficient testing" has not been defined. It is recommended that post mod testing of the manual gate valve top works should include collection of vibration data including collection of data at pump speeds above 1500 RPM.	32	20214019
29	Repetitive failures of yoke nuts have been established (valve F060A, F077). It is recommended that the failure of these components should be addressed in the recommended failure mode assessment.	32	20214019

Table 1
'B' Reactor Recirculation Pump
NRC Questions 12/01/04

30	It is recommended that a disassembled valve inspection should be done to conclusively determine the current condition of the F050A/F060A valve internals. If indications are noted for the F060A valve, a similar inspection of valve F060B should be conducted. The proposed radiograph would only provide an indication of gross damage and general condition and would not be expected to yield indications of loose connections	32	20214019
31	The current plan states that noise monitoring will be conducted during power ascension. Component degradation does not generally start for weeks to months into the operating cycle. It is recommended that the monitoring system should be available and/ or the program implemented, as needed, during the full operating cycle.	32	20214020
32	During the spring 2004 outage, modification to repair the failed cylinder of valve F050A included replacement of like for like parts. Initial walk down conducted during RF12 note indications that the actuator cylinder exhibits play. Therefore, there is reason to believe that these components will continue to fail if simply replaced. It is recommended that valve operator should be modified during RF 12.	33	20214019
33	The inspection activity task for inspection of valves similar in design to FA050A should define the specific attributes to be inspected. General instructions such as "visual inspection" may not be sufficient to address the intent of the inspection. Both Design Engineering and the responsible discipline engineer should contribute to the planned inspection instructions.	33	20214019
34	It is recommended that the small bore connection noted by radiography with a weld anomaly be included in the ISI program for continued augmented radiographic examination at each outage until system vibration issues are resolved.	44	20214041
35	It is recommended that each small bore connection to the RHR system in the vicinity of the areas of the past pipe and equipment failures, be examined with surface and visual examination at each outage until system vibration issues are resolved.	44	20214041

12-17-04 NRC Meeting Follow-up Action Items

Action Item 1:

Provide objective information on the aux impeller rubbing. Provide vibration data (orbital data) that shows rubbing is no longer a concern.

PSEG Response:

The diametrical clearance between the auxiliary impeller and the pump stuffing box is 40-50 mils. The radial clearance between the tip of the auxiliary impeller and the side of the stuffing box is 20-25 mils. The hydrostatic bearing radial clearance is 13-15 mils. In April 2000 (RF09), the motor was moved 15 mils to correct its alignment to the pump. This amount of motor movement indicates that, prior to RF09, when 'B' Reactor Recirculation pump was idle, both the hydrostatic bearing and the auxiliary impeller tip were located very close to their respected stationary components. Whenever the pump was started, both components could have rubbed until the pump discharge pressure was high enough for the hydrostatic bearing to center the pump shaft. Once the pump was in service, the shaft was centered at the hydrostatic bearing, and there was no additional rubbing of the bearing until the pump is secured. The centering of the shaft also moved the auxiliary impeller away from the side of the stuffing box, and there was no additional rubbing of the stuffing box until the pump is secured. Once 'B' Reactor Recirculation pump was realigned during RF09, the shaft was properly centered, and there has been no additional rubbing.

This rubbing was not evident in the pump's vibration data. This is due to the stiffness of the hydrostatic bearing maintaining the bearing journal and the auxiliary impeller centered at normal running speeds. A review of 'B' Reactor Recirculation pump vibration noted a small decrease in the 2X running frequency vibration component after the RF09 alignment corrections, but the vibration history and orbital plots display no indication of an internal pump rub either before or after RF09.

The scratches in the stuffing box were first identified during the March 2003 mechanical seal replacement. During the RF12, November 2004 mechanical seal replacement, a Flowserve field engineer inspected the scratches. The scratches were determined to be 1-2 mils deep based the physical feel of the scratches; and determined to be old based on the scratches having a white oxide layer vice a shiny, fresh metal appearance, and finding no metal filings in the bottom of the stuffing box.

Action Item 2:

Provide pump drawing that shows all clearances (including auxiliary impeller)

PSEG Response:

Drawing provided on 12/20/04 to NRC Region I

12-17-04 NRC Meeting Follow-up Action Items

The Hope Creek reactor recirculation pumps are displayed in Byron Jackson Drawing 1E-3429-4, which is located in the pump vendor manual, PN1-B31-C001-0124. The drawing is attached. The drawing provides the following diametrical running clearances:

Lower Wear Rings	100 -104 mils
Upper Wear Rings	50 - 54 mils
Hydrostatic Bearing	26 - 30 mils
Thermal Mixing Region	49 - 53 mils
Gland Plate Clearance	50 - 56 mils

The diametrical clearance between the Auxiliary Impeller OD and the Pump Stuffing Box ID is not given on the drawing and is 40-50 mils. This clearance was provided from a Flowserve review of reactor recirculation pump design drawings, which are not available to PSEG-Nuclear.

Action Item 3

New vibration monitoring plan, including 2x, phase angle. Show criteria and actions.

PSEG Response:

See the "12-17-04 NRC Meeting Follow-up Questions, Attachment 1" of this Enclosure for the Hope Creek Reactor Recirculation Pump/Motor Vibration Monitoring Plan.

Action Item 4

Additional restrictions/monitoring plan for startup of recirculation pumps. Is it proceduralized? What details will we use?

PSEG Response

See the "12-17-04 NRC Meeting Follow-up Questions, Attachment 1" of this Enclosure for the Hope Creek Reactor Recirculation Pump/Motor Vibration Monitoring Plan.

12-17-04 NRC Meeting Follow-up Action Items

Action Item 5:

What will Operators response be to 11 mils, reduce speed, 11 mils again ... minimum speed and still 11 mils. NRC suggested that this response should be proceduralized.

PSEG Response:

Alarm Response Procedure HC.OP-AR.ZZ-008 for "High Recirculation Pump Vibration" will be revised to direct operators to HC.OP-AB.RPV-0003 (Reactor Recirculation System Abnormal Operating Procedure) for actions to clear the high vibration condition.

HC.OP-AB.RPV-0003 will direct operators to reduce recirculation pump speed to clear the high vibration alarm.

Further direction will be provided to remove the affected recirculation pump from service if the alert setpoint cannot be maintained clear and the affected recirculation pump speed has been lowered by >20%.

These procedure revisions will be in place prior to the start of the reactor recirculation pumps.

Action Item 6

Provide Drywell Monitoring DCP

PSEG Response:

Preliminary release of DCP provided to NRC Region I on 12/20/04. The final DCP package (80062466) was provided to NRC on 12/28/04.

Action Item 7

What information do you have to demonstrate monitoring will detect crack propagation? How are we going to flag shaft issues? What is best method to detect pending problems? How will we monitor and at what frequency?

PSEG Response:

See the "12-17-04 NRC Meeting Follow-up Questions, Attachment 1" of this Enclosure for the Hope Creek Reactor Recirculation Pump/Motor Vibration Monitoring Plan.

12-17-04 NRC Meeting Follow-up Action Items

<u>Action Item 8</u>

Relocate axial probes to correct location for recirculation pumps. Will this be done prior to restart?

PSEG Response:

The current location of the vibration probe on the reactor recirculation pump motors is correct in accordance with the standard designs for the General Electric reactor recirculation motor, and the Flowserve reactor recirculation pump. The current design description and setpoints are incorrect for this probe. Both of these issues will be corrected prior to restart.

The Hope Creek reactor recirculation pump motors are General Electric (GE) Model 5K46385AC1, 7500 HP, AC motors. A review of the vendor manual VTD PN1-B31-C001-0119 found no guidance related to axial or radial vibration monitoring or indication. The vendor manual does discuss a Vibraswitch Malfunction Detector, which is installed on the side of the motor in the radial direction. The vibration monitoring of the motors was discussed with GE who reported that the original and current design to monitor recirculation pump motor vibration is to mount one (1) vibration probe near the top of the motor in the radial direction.

The Hope Creek reactor recirculation pumps are Byron-Jackson (now Flowserve) Type DVSS, size 28x28x35, vertical, single stage pumps. A review of the vendor manual VTD PN1-B31-C001-0124 found no guidance related to axial or radial vibration monitoring or indication. The vibration monitoring of the pumps was discussed with Flowserve who reported that the Byron Jackson primary pumps were not originally supplied with shaft proximity probes; as such, instrumentation was not prevalent in the era in which they were built. Thus, no recommendation for the location of such probes was provided in the original pump vendor manual. Most reactor recirculation pumps have been retrofitted with proximity probes. The preferred vibration instrumentation from Flowserve's perspective would be proximity probes. The Flowserve recommendations do not include axial vibration detection. The axial clearances in the pump are very large when compared to the axial clearances of the motor thrust bearing; therefore, axial vibration is not a concern with reactor recirculation pumps.

12-17-04 NRC Meeting Follow-up Action Items

Action Item 9

Provide status of S&L recommendations.

PSEG Response:

Status provided in a separate Excel spreadsheet enclosed with this letter. [Attachment 2 of Enclosure 2]

Action Item 10

Is phase angle and frequency peaks a valid method to detect problems?

PSEG Response:

Phase angle and frequency peaks are a proven method for detecting shaft cracking problems. Several technical studies have been performed associated with pump shaft cracking. The attached Bentley Nevada Technical Bulletin, "Early Shaft Crack Detection on Rotating Machinery Using Vibration Monitoring and Diagnostics," was utilized in the preparation of the Vibration Monitoring Plan. This bulletin outlines the proper methods to diagnose a shaft crack as unexplained changes in the 1X amplitude and phase angle, increase in the 2X amplitude, and changes in orbital pattern.

A case history was performed on the 3rd Generation reactor recirculation pump shaft cracks and published in Orbit Magazine in December 1990. It described the initial indications of the shaft crack to be an increase in 1X and 2X accompanied by significant phase angle shifts.

Action Item 11

Provide HPCI exhaust data requested

- i. **Lisega Final Report**
- ii. **1-P-FD-006-H06 lug examination**
- iii. **1-P-FD-006-H19 lug examination**
- iv. **Installation records (WO & DCP paper) for snubber with cold set problem**
- v. **Provide calculation C-0031**
- vi. **Wall thickness (SC-0270)**
- vii. **Follow up to item (iv) above. Lisega technical manual states to perform an annual inspection of snubber installation position. Provide records of this inspection or justification for not doing the inspection.**

PSEG Response:

Item i sent to NRC via email on 12/23/04.

12-17-04 NRC Meeting Follow-up Action Items

Item **iv** sent to NRC via overnight on 12/22/04.

Item **v** (Calculation C-0031) and Item **vi** (Calculation SC-0270) sent to NRC Region I on 12/16/04.

Item **vii** response is as follows:

The Hope Creek ISI Snubber testing program has been followed which is based on GL 90-09 and Visually inspects 50% of the plant snubber population every outage, alternating accessible and non-accessible, or 100% every other outage. This is documented in our Hope Creek Snubber Technical Specification 3 /4.7.5, Engineering Technical Standard NC.DE-TS.ZZ-3067(Q) and Snubber Examination and Testing Procedure SH.RA-ST.ZZ-0105(Q). The Lisega Document 87003-4-4603 is a Maintenance Recommendation and they support the Visual Examination frequency we have included in our Technical Specification Snubber program.

Snubber FD-006-H022 past history

Maintenance plan# 14643
Maintenance item# 15893
Equipment# 10105556
RT/Exam# 771111

RFO12- 50080793 - 5 3/8"
RFO11- 50058852 -5 1/2"
RFO10- 50034827 - 5 1/2"
RFO8 - 980714085 - 5 1/2 - First VT after swap 18 months - MMIS - (pre-Snubbworks)
RFO7 - 970915562 - Lisega swap out - 5 1/2" - snubber installed as-is due to the thermal movement of 1/16".

<u>**Action Item 12**</u>

List past maintenance items on RHR and Recirculation system that were from fatigue or vibration.

PSEG Response:

The following is a list of degraded conditions on the Reactor Recirculation and RHR systems that have been attributed to piping vibration. The information from start up to the Spring '04 outage has been extracted from Common Cause Evaluation H-1-BB-CEE-1862 (70037702). The Common Cause Evaluation concentrated on components with a history of degraded conditions. In addition a review of the maintenance history was performed of all components directly connected to the 28" large bore Recirculation piping, 20" RHR return piping, and both 12" RHR supply lines. The review encompassed all maintenance work that is in the SAP database from 6/12/1999. The review concluded that the work performed on the components was primarily routine in nature. None of the components other than the components addressed in the Common Cause Evaluation showed problems that could be attributed to vibration.

The information from the Spring '04 outage to the present (12/18/04) has been extracted from a review of notifications in SAP with a system code of BB and BC. The information concludes that the identified problems are on components that have experienced signs of vibration degradation in the past. The only exception is the vibration-induced wear between a hanger and a 1" pressure sensing line.

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, which 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.

12-17-04 NRC Meeting Follow-up Action Items

Table 6-6

Incidents Related to Handwheels on the F060A and F060B Valves

Valve	Notification	Description of as-found condition	Actions taken
F060A	10/05/94 940311074	The handwheel has been sheared from the stem. Disassemble manual operator, replace handwheel shaft, reassemble operator.	Replace pinion shaft and bearing on handwheel. As found condition: Broken shaft on handwheel. Repair actions taken: Replaced shaft.
F060B	03/08/91 910114145	Valve handwheel has sheared off and valve is binding when stroked.	Replaced pinion and bearings
	03/03/93 921023060	Handwheel has fallen off. Replace missing hardware and install handwheel.	Installed handwheel using new adapter - wrench and fasteners.
	04/28/94 940322283	1BCV-074 jammed open hand wheel found on ground.	Installed new handwheel and wrench adapter on valve 1BCV-074. Pinion shaft found sat. Intact.
	05/30/96 951129248	1BC-V074 B loop LPCI manual isolation valve has a detached handwheel for the third outage in the last four. Previous work requests 921023060 and 940322283. The valve is a manual 1000 turn valve to operate.	Located valve in drywell. Pinion shaft is broken on handwheel end needs to be replaced. Chased female threads and male threads with die and tap. Note. Male threads on shaft are no good they are rolled over). Applied Loctite 242 to flats and thread to assist in holding handwheel in place. Operations needed handwheel on valve to change position of valve. As-found condition: Piece is missing on handwheel end. Threads are chipped out. Went to the jobsite removed the old pinion gear and installed a new one.

The following notifications identify problems with the hand wheels and are addressed in the report but not listed in the table above:

- 20182738 F060B
- 20183448 F060A

The following notification identifies the problem with the actuator on the F050A as discussed in the report:

- 20182397

12-17-04 NRC Meeting Follow-up Action Items

Table 6-7

History of F060A and F060B Limit Switch Problems

Valve	Notification	Description of as-found condition	Actions taken
1BCHV-F060A	02/08/91 910110174	1BCZS-F060A-E11 Sealtite for limit switch is separated, and open showing cable inside. Limit switch is for manual valve v183 in drywell Elevation 0 AZ270. Please repair/replace Sealtite. Verify operability.	Cut back of seal tight and replaced snap ring on swivel. Piece of connector satisfactory.
	11/30/92 920908081	Indication lights for F060A on 10C650a are out. Performed lamp check, which was sat. Problem is not with bulbs or carriage. (Valve is located in the drywell.) Troubleshoot and rework any fault.	Original - verified open and closed limit switches from valve. 1BCV-183 to light indication in the control room 1BCZIL-F060A-E11. The retaining ring on the lock ring adaptor has come off. The lock ring adaptor has been damaged. Therefore, the retaining ring will not stay on. The lock ring kit will be addressed under work order 921012186. As-found condition: Lock ring adaptor separated from quick disconnect.
	02/07/96 960112073	During tour of area, it was noted that the lower Sealtite connector where the Sealtite goes into the switch was broken.	Reworked named connector by reseating C-ring. Closed switch. Indication of 1BCZS-F060A-E11 satisfactory. As found: C-ring of NAMECO connector loose. Repair actions: Reworked/ reseated C-ring of connector. Failure cause: Poor work practices in area/pushing climbing on cables.
	10/18/03 20162879	Indication on 10C650A for 1BCZIL-F060A 'A' SDC manual isolation valve has been lost. Light bulbs tested satisfactory.	
	03/21/04 20182396	The limit switch actuator arm and rod for valve F060A are broken and missing. The failure appears to be from severe vibration... Control indication is unavailable. Part needs to be located in the drywell.	Replaced broken hardware and repositioned open limit switch setting.

12-17-04 NRC Meeting Follow-up Action Items

Table 6-7

History of F060A and F060B Limit Switch Problems

Valve	Notification	Description of as-found condition	Actions taken
	5/12/04 20189454	The position indication on panel 10C650 in the Hope Creek main control room for the RHR Shutdown Cooling manual isolation valve H1BC -1BCZS-F060A-E11 is failing. Currently, the "open" indication is flashing. Open indication flashed about 1-2 times/sec for about one hour and then the open indication extinguished. After several hours of no indication, the closed indication illuminated solid with the open light extinguished.	
1BCHV-F060B	09/13/85 SDR BC-0951	The manual limit switch actuating pawl on manual valve 1BC-V074 is too short to properly engage the limit switch. For the operator, 1BC-ZS-F060B.	Either weld an extension onto the existing pawl or else fabricate a new pawl for 1BC-074 (1BC-ZS-F060B). Reference: Microfiche role 30029, frame 1660
	5/04/00 20028812	The present limit switch connector going back to the junction box has a broken snap ring. The snap ring holds the seal tight to the EQ connector.	
	10/17/01 20080472	While performing OP-IS-BC-0105, the limit switch for 1-BC-V074 indicated dual in the MCR. Limit switch was fingered in the field to get the valve to indicate open but the limit switch needs adjusted to properly hit the striker plate.	Installed new cap screws for gearbox cover/limit switch mounting plate. Adjusted limit switches for proper operation. OPS retested valve, indication satisfactory.
	5/01/03 20142410	During RF11, it was noted that 1BCZS-F060B has no indication in the control room when being manipulated. An operator was sent into the drywell and noted that the limit switches looked bad and could not be moved. It was reported that once the valve was off its closed seat, the closed limit moved freely and the open limit was stiff. When the valve moved close, after the limits were able to be moved, there was still no close indication in the control room. A full open indication was seen in the control room when the valve was in its open position.	

12-17-04 NRC Meeting Follow-up Action Items

Table 6-7

History of F060A and F060B Limit Switch Problems

Valve	Notification	Description of as-found condition	Actions taken
	5/27/03 20146178 and 10/24/03 20163786	20146178: H1BC -1BCZS-F060B-E11 indicates dual. 20163786: On 5/27/2003, H1BC-1BCZS-F060B (notification 20146178) showed a dual indication. The F060B is a normally open RHR shutdown cooling manual injection valve, associated with the recirc loop. The purpose of this valve is to allow flow to be taken from the B recirc loop, and return this flow via the respective RHR HX to the A or B recirc loop. The dual indication for this valve was caused by a limit switch failure; this limit switch has an extensive history of failure. During RF11, the limit switch mounting was inspected and it was found that the closed switch was tight against the operator switch arm plate. The contractor supervisor said that, during installation, the switch arms are set at the same angle every installation, and not adjusted after replacement.	
	3/21/2004 20182395	Limit switch actuator arm and rod are broken. The failure appears to be from severe vibration as indicated by the failure of the handwheel on the valve. This is a repeat issue from previous failures. Control room indication is unavailable.	Replaced broken hardware and repositioned open limit switch setting.
	5/15/2004 20189888	RHR valve F060B indicates dual in the main control room. This may be caused by vibration.	

12-17-04 NRC Meeting Follow-up Action Items

List of Notifications From Spring '04 to 12/18/04

20212106	11/19/2004	4	3 C-WCMP53	H1BB -1-P-BB-226-H005	VIBRATION DEGRADATION [70042945]	60050184
20212662	11/23/2004		3 E-EDC00	H1BB -1-P-BB-226-H005	VIBRATION DEGRADATION ON HANGER	70042945
20214782	12/8/2004	4	3 E-EDC01	H1BB	DEGRADED SMALL BORE RECIRC PIPE	70043504
20188684	5/5/2004	1	3	H1BC -1BC006F001	NOISENORTH PIPE CHASE (70039228)	
20189624	5/12/2004	1	3 E-EDC00	H1BC -1BCZS-F060A-E11	POWER REDUCTION DUE TO VIBRATION	70039157
20189888	5/15/2004	4	3 H-MC	H1BC -1BCZS-F060B-E11	CRI-(R12) F060B INDICATES DUAL	60045532
20208116	10/21/2004	4	3 H-MC08	H1BC -1BCZS-F060A-E11	LIMIT SWITCH ON BCF060A	60045706
20208117	10/21/2004	4	3 H-MC08	H1BC -1BCZS-F060B-E11	LIMIT SWITCH ONBCF060B	60045532
20208118	10/21/2004	4	3 E-ESF16	H1BC -1BCZS-F077-E11	GEAR BOX COVER BCF077	80072763
20208119	10/21/2004	4	3 H-MC08	H1BC -BC-HV-F050A	CRI-(RDYT) PROBLEMS WITH BCF050A	60049164
20208920	10/28/2004	4	2 H-M	H1BC -1-BC-V183	HANDWHEEL OP SPINS FREELY [70042298]	60049009
20209604	11/2/2004		3 E-PGVE00	H1BC -1-BC-V183	HANDWHEEL OP SPINS FREELY N1-20208920	70042298
20212370	11/21/2004	4	2 H-MM12	H1BC -1-BC-V183	UNABLE TO OPEN 1-BC-V183	60049009
20214384	12/6/2004		3 E-PGVE00	H1BC -1BCSV-F050A-E11	ACTUATOR STEM BIND N1-20213898	70043054

Action Item 13

Provide Rev 1 of Engineering Evaluation for Recirculation Pump.

PSEG Response:

Revision 1 of H-1-BB-MEE-1878 provided to NRC Region 1 on 12/20/04.

Action Item 14

Power source for the recirculation pump isolation valves?

PSEG Response:

The power source for the recirculation pump isolation valves is non-safety related (non Class 1E).

Action Item 15

Re-location of the vibration probes on the recirculation pump had no impact on the measurement of the vibration levels. Flowserve does not have a recommended location for the probes. Please provide documentation from Flowserve that confirms these statements.

12-17-04 NRC Meeting Follow-up Action Items

PSEG Response:

Flowserve was contacted and provided the above question. The full text of their response is provided below. In the first paragraph, they confirm that Flowserve did not provide a recommended location for the vibration probes when the pump was initially delivered.

In the second paragraph, Flowserve describes the vibration probe location recommendation that they would provide when requested. In the case of Hope Creek, the vibration probes for 'A' Reactor Recirculation pump are located on the lower flange of the spacer coupling. The vibration probes for 'B' Reactor Recirculation pump are located on the pump half coupling, which is acknowledged by Flowserve to be a reasonable alternative. During RF12, the following maintenance was performed on the pump half coupling:

(a) The bore was verified to be concentric to within 1.5 mils.
(b) The OD was verified to be round to within 1 mil.
(c) The OD surface was polished to provide a clean surface for the proximity probe.

In the third paragraph, Flowserve describes inaccuracies that can be induced into a pump's vibration indication due to age of the pump, and inconsistencies (i.e. variations in coupling stack-up, runout in the pump shaft, or possible internal wear of hydrostatic bearing or wear rings) imparted into the pump's alignment due to its maintenance history. These changes in the pump are part of the component aging process, and except in rare cases, will lead to elevated vibrations.

The following is the full text of the Flowserve response:

"**From:** David Zagres [mailto:DZagres@flowserve.com]
Sent: Monday, December 20, 2004 7:24 PM
To: Koppel, Peter J.
Cc: Frank Costanzo; David Krupp
Subject: Re: Request for Information

Peter,

As we discussed, Byron Jackson primary pumps were not originally supplied with shaft proximity probes, as such instrumentation was not prevalent in the era in which they were built. Thus, no recommendations for the location of such probes was provided in the original pump instruction manual. Most primary pumps were retrofitted with proximity probes by the utility or third parties, typically without consultation to Byron Jackson (later BW/IP, and now Flowserve).

The preferred location from Flowserve's perspective is the lower flange of the spacer coupling, as this diameter is trued to the rotational centerline of the complete assembly as part of the coupling stackup so a true reading of shaft vibration is obtained rather than the roundness or eccentricity of any given surface. The upper flange of the pump half coupling would be a reasonable alternative, as it was typically trued to the element centerline as well.

However, given the number of field modifications which have occurred on the Hope Creek RRPs without our involvement, as well as the suspected presence of a shaft bow, we can not be certain that either of these locations maintains absolute alignment to the axis of the hydrostatic bearing journal, pump impeller wear rings, recirc impeller, or thermal barrier region of the shaft. This consideration must be included in the evaluation of vibration data taken on this pump.

Best regards,

David Zagres
Section Head, Nuclear Primary Engineering
Nuclear Products Operations
Flowserve Pump Division

Action Item 16

What is the strength of the Recirculation Pump shaft material? The S&L report uses nominal values. Do we have specific material strengths following the manufacturing of the shaft?

PSEG Response:

The actual tensile and yield stress values of the Hope Creek 'B' Reactor Recirculation pump shaft material for the H1BB -1B-P-201 (S/N 711-S-0765) are as follows per the Certified Materials Test Report (CMTR) from fabrication by Flowserve (Byron Jackson Pump Division):

Tensile Strength: 34.4 ksi
Yield Strength: 77.9 ksi

The shaft was fabricated IAW ASTM A182 F304. The heat used to manufacture the shaft was 3A4-8082633 per the CMTR.

Action Item 17

Follow up to Question 15 response: The Flowserve response did not address the impact of the movement of the vibration probes during RF10. Did movement of the probes (to pump hub flange) affect the measured vibration levels?

PSEG Response:

Flowserve is not in a position to definitively answer whether or not the re-location of the vibration probes had an impact on the measured vibration levels.

The reason Flowserve can not provide a definitive answer is due to various unknown possible inconsistencies in the pump's current condition that have developed over 17 years of operation and maintenance. Those inconsistencies include variations in coupling stack-up, runout in the pump shaft, and possible internal wear of hydrostatic bearing and wear rings. Since neither Public Service nor Flowserve have precise data on the exact condition of the 'B' Reactor Recirculation pump internals, Flowserve cannot definitively determine if the re-location of the vibration probes had an impact on the measured vibration levels. Flowserve replied that the current location of the vibration probes, the pump half coupling, is an acceptable location for the vibration instrumentation.

Action Item 18

Provide the Bechtel Piping Design Specifications for the HPCI Exhaust Line.

PSEG Response:

Copy provided to NRC Region I on 12/23/04.

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

Purpose:

Monitor the vibration for 'A' & 'B' Reactor Recirculation pumps and motors in order to:

1) Trend the general health of the reactor recirculation pumps and motors.
2) Provide an early warning of possible reactor recirculation pump shaft cracking.

Monitoring Plan:

1) Continuous Monitoring by Operations Department - The Hope Creek reactor recirculation pumps are monitored continuously while in service:

- The pump radial vibration is monitored by two proximity probes (X and Y directions) located on the pump coupling and are processed through installed vibration monitoring system.
- The overall pump radial vibration levels are utilized three ways:
  (1) Displayed on the Plant Computer in Control Room Operators record the vibration levels on their daily control console log, HC.OP-DL.ZZ-0003(Q).
  (2) Recorded on the Plant Historian for engineering to trend.
  (3) Alarmed in the control room via overhead alarm C1-E4, REACTOR RECIRC PUMP VIB HI, and digital alarm points D5351 and D5352. Alarm setpoints:
  Pump Vibration Alarm - 11 mils
  Pump Danger Limit - 16 mils
- The control room operators have guidance for responding to the vibration alarms in procedures:
  (1) HC.OP-SO.BB-0002(Q), Reactor Recirculation System operating procedure.
  (2) HC.OP-AR.ZZ-0008(Q), Alarm Response procedure
  (3) HC.OP-AB.RPV-0003(Q), Recirculation System Abnormal procedure.

2) Component Trending by Engineering Department - The Hope Creek reactor recirculation pumps are monitored periodically by engineering:

- A procedure, HC.ER-AD.BB-0001(Z), is being developed to provide instruction and documentation of the Reactor Recirculation Pumps vibration monitoring.

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

- Startup Vibration Monitoring: The reactor recirculation pump start-up vibration levels will be monitored during each scheduled pump start.

  (a) Connect vibration monitoring equipment to the reactor recirculation pump radial vibration indication at the SMART monitor prior to each scheduled initial pump start.
  (b) Review the maintenance performed on the reactor recirculation pump since the previous pump start.
  (c) Review vibration data from the previous start of the reactor coolant pump to use as comparison.
  (d) Record vibration amplitudes and phase angles at specific intervals, on attached data sheets, as the reactor recirculation transitions from the low speed stop to 100% flow.
  (e) Compare the collected data collected during the previous pump start.
  (f) IF any phase angle reading differs by more than 30° or any magnitude differs by more than 50%, recommend the control room to decrease pump speed as necessary to restore the vibration level into the acceptable band, while the data is evaluated.
  (g) As sufficient start-up vibration data is collected, specific magnitude and phase angle criterion will be established using the ASME OM-5/G-2003 standard.
  (h) Recommend actions based on criteria established in the procedure attachments.
  (i) Notify the control room with the results of this data collection.
  (j) A copy of the completed procedure attachments to will be forwarded to Component Engineering for trending, and submitted with the completed workorder for permanent documentation.

- In Service Vibration Monitoring: The reactor recirculation pump vibration levels will be monitored during the operating cycle.

  (a) The periodicity of vibration data collection is determined by maintenance plans in the station's preventative maintenance program. The initial periodicity is set at Bi-weekly for the first four weeks. Once a trend is established, the periodicity will be

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

changed to weekly for the remainder of the cycle. Additional periodicity changes may be necessary depending on the pump performance.

(b) Connect vibration monitoring equipment to the reactor recirculation pump radial vibration indication at the SMART monitor.
(c) Record vibration amplitudes and phase angles as specified on the data sheets attached.
(d) Compare the data collected against the criteria supplied in the procedure.
(e) Recommend actions based on criteria established in the procedure.
(f) Review the orbital plots for any indication of shaft cracking. Shaft cracks are indicated by a figure eight pattern to the orbital plot.
(g) Notify the control room with the results of this data collection.
(h) The vibration data will up updated onto a spreadsheet for trending purposes.
(i) A copy of the completed procedure attachments to will be forwarded to Component Engineering for trending, and submitted with the completed workorder for permanent documentation

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

Sample Procedure Data Sheets

(Start-up Data Sheets)

Reactor Recirculation Pump Start-up Vibration Monitoring Table

Date ___________

____ Reactor Recirculation Pump

Maintenance Performed since last pump start:

30% Flow RPM			
Vibration Peak	**Magnitude**	**Phase Angle**	**Comments**
1X	mils		
2X	mils		

50% Flow RPM			
Vibration Peak	**Magnitude**	**Phase Angle**	**Comments**
1X	mils		
2X	mils		

70% Flow RPM			
Vibration Peak	**Magnitude**	**Phase Angle**	**Comments**
1X	mils		
2X	mils		

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

80% Flow RPM			
Vibration Peak	Magnitude	Phase Angle	Comments
1X	mils		
2X	mils		

90% Flow RPM			
Vibration Peak	Magnitude	Phase Angle	Comments
1X	mils		
2X	mils		

100% Flow RPM			
Vibration Peak	Magnitude	Phase Angle	Comments
1X	mils		
2X	mils		

Data Collected by: ______________________________

Data Reviewed by: ______________________________

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

(In-Service Data Sheets)

Periodic Reactor Recirculation Pump Vibration Monitoring Table

Date ___________

'A' Reactor Recirculation Pump

Vibration Peak	Magnitude	Phase Angle	Comments
1X	mils		
2X	mils		

'B' Reactor Recirculation Pump

Vibration Peak	Magnitude	Phase Angle	Comments
1X	mils		
2X	mils		

Results of Orbital Plot Review:

Data Collected by: ________________________________

Data Reviewed by: ________________________________

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

Operations Monitoring Criteria and Required Actions

1) These tables are utilized by the operators using control indications to perform continuous vibration monitoring.
2) The setpoints were developed using Engineering Calculation SC-BB-0522 and Vendor guidance.

Vibration Level	Parameter	Channel/Point#	
7 mils	Reactor Recirculation motor vibration alarm.	VSH7910A4 A2602 D5351	VSH7910B4 A2604 D5352
13 mils	Reactor Recirculation motor danger limit.	VSH7910A4 A2602	VSH7910B4 A2604
11 mils	Reactor Recirculation pump vibration alarm.	VSH7910A1 A2601 D5351	VSH7910B1 A2603 D5352
16 mils	Reactor Recirculation pump danger limit.	VSH7910A1 A2601	VSH7910B1 A2603
25 mils	Reactor Recirculation pump vendor limit.	TechNote 9309-08-022	

Vibration Level	Parameter	Required Actions
7 mils	Reactor Recirculation motor vibration alarm.	1) Lower pump speed to lower vibration level. 2) If vibration levels do not lower below 7 mils remove pump from service.
13 mils	Reactor Recirculation motor danger limit.	Remove pump from service.
11 mils	Reactor Recirculation pump vibration alarm.	1) Lower pump speed to lower vibration level. 2) If vibration levels do not lower below 11 mils remove pump from service.
16 mils	Reactor Recirculation pump danger limit.	Remove pump from service.

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

Engineering Monitoring Criteria and Required Actions

1) These tables are utilized by the engineers performing the periodic vibration data collection.
2) The setpoints were developed using ASME OM-5/G-2003 standard for Determining 1X and 2X Vector Acceptance Regions. Historical vibration data collected during Cycle 12 (April 2003-November 2004) was used to develop the amplitude and phase angle criterion.

'A' Reactor Recirculation Pump
Phase Angle Criteria and Required Actions

Parameter	Direction	Phase Angle Criteria	Required Actions for values outside the criteria
1X Magnitude	X	120° - 150°	1) Immediate review of data by Component Eng. with recommendations to operations. 2) Initiate Notification
	Y	195° - 225°	
2X Magnitude	X	285° - 225°	
	Y	225° - 135°	

'A' Reactor Recirculation Pump
Vibration Amplitude Criteria and Required Actions

Parameter	Direction	Amplitude Criteria	Required Actions for values outside the criteria
1X Magnitude	X	2.8 - 3.5 mils	1) Immediate review of data by Component Eng. with recommendations to operations. 2) IF vibration amplitude is high contact control room and recommend decreasing pump speed to restore vibration to within the acceptable criteria. 3) Initiate Notification
	Y	0.8 - 3.9 mils	
2X Magnitude	X	0.0 - 0.3 mils	
	Y	0.0 - 0.3 mils	

Attachment 1
Hope Creek Reactor Recirculation Pump/Motor
Vibration Monitoring Plan

'B' Reactor Recirculation Pump Phase Angle Criteria and Required Actions			
Parameter	**Direction**	**Phase Angle Criteria**	**Required Actions for values outside the criteria**
1X Magnitude	X	285° - 300°	1) Immediate review of data by Component Eng. with recommendations to operations. 2) Initiate Notification
	Y	000° - 030°	
2X Magnitude	X	255° - 285°	
	Y	060° - 150°	

'B' Reactor Recirculation Pump Vibration Amplitude Criteria and Required Actions			
Parameter	**Direction**	**Amplitude Criteria**	**Required Actions for values outside the criteria**
1X Magnitude	X	7.0 - 8.2 mils	1) Immediate review of data by Component Eng. with recommendations to operations. 2) IF vibration amplitude is high contact control room and recommend decreasing pump speed to restore vibration to within the acceptable criteria. 3) Initiate Notification
	Y	7.0 - 8.2 mils	
2X Magnitude	X	0.5 - 1.1 mils	
	Y	0.2 - 0.5 mils	

"B" Reactor Recirculation Pump
Action 9 SL recommendations status

Item	Notification	Order	Description	Due	Owner	Status	Restart
1	20213970	70043209	The Reactor Recirculation (RR) pumps speed is limited to 1510 rpm, and at this speed the maximum core flow achieved in the past was 103 million. During the last operating cycle the flow dropped to approximately 100 million. The reduction may be due to instrument changes, RR pump degradation or to jet pump fouling. If the latter is deemed a significant operational concern, it should be investigated during RF12.	Complete	Kordziel	Complete	Yes
2	20214011	70042927	The RR pump instrumentation being added is being installed per a temporary modification. An effort should be initiated to make the instrumentation a permanent installation. This would include the data acquisition and recording devices and control room interfaces that would be required for the permanent installation.	12/31/04	Koppel	A detailed monitoring plan will be in place prior to plant startup. A draft plan has been developed	Yes
3	20214011	70042927	Review RR pump instrumentation at other plants, including how the data from the instrumentation is being used, to help verify that the type and amount of instrumentation being added is appropriate.	12/31/04	Koppel	Industry survey is in progress.	Yes
4	20214012	70042928	The difference in Hope Creek "A" and "B" pump rigid restraint configuration should be investigated to ensure that it is not the cause for the high "B" RR pump vibrations.	12/24/04	Johnson	Reactor recirculation pump casing and piping analysis are being reviewed to assess impact	Yes
5	20214013	70042929	For the "B" RR pump, alignment of the coupling and checking alignment when the pump is recoupled during RF12 is recommended.	12/24/04	Koppel	Coupling alignment was checked during maintenance activities conducted in RF12.	Yes
6	20214013	70042929	The "B" RR coupling should be checked for concentricity and squareness, and balanced. Alternately, a new duplicate coupling may be available on short notice, from another plant, for replacement during RF12. If a new coupling is purchased, it should also be checked for squareness and balance.	12/24/04	Koppel	Existing coupling has been checked for concentricity and squareness, and balanced. This work is complete.	Yes
7	20214014	70042930	The Hope Creek RR pumps should be monitored closely. A rapid rise in vibration amplitude would be sufficient reason to shut the pump down immediately for an internal inspection and rotor replacement, as the window between the rise and potential shaft failure is expected to be small.	12/31/04	Koppel	A detailed monitoring plan will be in place prior to plant startup. A draft plan has been developed	Yes
8	20214014	70042930	The "A" pump should be monitored with the "B" pump, for capacity and vibrations. A rapid rise in vibration amplitude would be sufficient reason to shut the pump down immediately for an internal inspection and rotor replacement	12/31/04	Koppel	The monitoring plan will include "A" pump	Yes

"B" Reactor Recirculation Pump
Action 9 SL recommendations status

Item	Notification	Order	Description	Due	Owner	Status	Restart
9	20214017	70042931	Considering the age and time in service of the RR pumps, the Station should be prepared to rebuild the RR pumps because of capacity degradation or rapidly increase in vibrations.	12/31/04	Koppel	Planning is underway to have a package prepared to replace the recirculation pump if necessary prior to RF13.	No
10	20214017	70042931	The replacement "B" and "A" pump rotor on hand should be checked for rotor balance and shaft straightness before installing in the pump casings. New couplings included in the replacement packages should be checked for concentricity, squareness, and balance.	12/31/04	Koppel	Replacement shafts will be checked for runout and balance prior to installation in the plant	No
11	20214044	70042937	The DCP, installation plans, access and rigging plan, and inspection of the replacement parts should be done during or as soon after RF12 for replacement of "B" and "A" pumps.	12/31/04	F. Cook	Contingency plans will be in place by end of 1st Qtr 05.	No
12	20214017	70042931	The replacement pump parts on hand do not include seal cartridges. The intent is to rebuild existing seals at the Stations, using parts furnished by Flowserve. Instead, new generation seals with SiC stationary and rotating seal rings should be purchased. This should be done soon after RF12, in anticipation of an unscheduled outage.	12/31/04	Koppel	Next generation mechanical seals will be installed in both RR pumps in RF13	No
13	20214017	70042931	Both "A" and "B" RRPs have operated over 130,000 hours and are approaching a perceived end of useful life. Thus, it is recommended that the "B" RRP be upgraded during RF13 and "A" be upgraded during RF14, unless monitoring shows capacity or vibration degradation earlier. "B" RRP upgrade is recommended earlier than "A" because of the higher vibration levels.	12/31/04	Koppel	B pump will be replaced in RF13 and A pump replacement will be evaluated for RF14	No
14	20214017	70042931	More accurately estimate the time "A" and "B" pumps have operated. Collect similar data form other plants. Estimate the remaining life of the "A" and "B" pumps based on data from other plants.	12/31/04	Koppel	Industry shaft age comparisons have been performed and it is determined that Hope Creek shafts are in the middle of the population reviewed	Yes
15	20214018	70042932	The acceptance criteria for March 2004 monitoring were established by performing response spectrum analyses for frequencies up to 200 Hz. The frequency range is acceptable; however, response spectrum analyses are applicable when the piping is being shaken by the building structure. The axial forcing functions from flow-induced vibration result in a different relationship between maximum pipe stresses and displacements than forcing functions applied externally from the building structure. Therefore, analyses that simulate the axial forcing functions are more applicable for developing acceptance criteria for steady-state flow-induced vibration.	12/31/04	Johnson	The basis for using response spectrum based acceptance criteria is being developed	Yes

"B" Reactor Recirculation Pump
Action 9 SL recommendations status

Item	Notification	Order	Description	Due	Owner	Status	Restart
16	20214018	70042932	The March 2004 vibration monitoring acceptance criteria are in terms of displacement. When higher frequency harmonic excitation is monitored, as is the case with vibrations caused by vane pass frequencies, it is advisable to also establish an acceleration acceptance limits in addition to the displacement limits. This recommendation is applicable to EPU vibration monitoring.	12/31/04	Johnson	Acceleration criteria is part of the acceptance criteria being developed	Yes
17	20214018	70042932	For developing the acceptance criteria for the March 2004 monitoring, response spectrum was adjusted higher in the range of the 1X pump speed component. If the 5X component is also expected to be significant, the response spectrum should also be adjusted higher in that range. This recommendation is applicable to EPU vibration monitoring.	12/31/04	Johnson	The response spectra will be adjusted for the 5X component.	Yes
18	20214018	70042932	Vibration measurements at RR pump speeds above 1500 rpm are planned. Vibrations at these higher pump speeds could increase significantly, as evidenced by the reported "freight train effect" that occurs at pump speeds above 1510 rpm. Thus, more comprehensive monitoring of the RR and RHR piping than planned is warranted for EPU. This recommendation is applicable to EPU vibration monitoring.	12/31/04	Johnson	Additional transducers are being added to the piping systems in this refueling outage. The monitoring plan for increases in speed above 1510 will be done in 2005	No
19	20214019	70042933	The susceptible valve component should be included in the EPU vibration monitoring program. The most effective number of sensors required can best be determined from analytical models that provide accurate vibration response characteristics.	12/31/04	Johnson	The susceptible valve subcomponents monitoring are being instrumented in this refueling outage	Yes
20	20214042	70042936	It is planned to determine the acoustic characteristics of the RR system. In order to benchmark the acoustic model, dynamic pressure data should be collected measured near the source of the pressure pulsations (e.g., the RR pumps) and at locations where maximum acoustic responses may occur (e.g., near closed valves) during power ascension up to the maximum speeds at which the RR pumps will be operated.	Transducer installation - 12/24/05 Model development - 12/05	Johnson	Transducers to benchmark the acoustic model have been installed in this refueling outage. The model will be developed in 2005.	No
21	20214042	70042936	The acoustic modes predicted by the acoustic model will be strongly dependent on the speed of sound used in the analysis. Means for benchmarking the acoustic velocity used in analytical models should be investigated.	12/31/04	Johnson	The appropriate speed of sound in the reactor recirculation system will be investigated and used.	No
22	20214018	70042932	The signals from the RR pump vibration and speed sensors should be tied into the data acquisition system used for EPU vibration monitoring so they can be directly correlated to the system vibration and acoustic responses. This will provide an understanding of the interaction between the pump and system responses.	12/31/05	Johnson	This recommendation is being evaluated.	No

"B" Reactor Recirculation Pump
Action 9 SL recommendations status

Item	Notification	Order	Description	Due	Owner	Status	Restart
23	20214018	70042932	The vibration acceptance limits should be in terms of peak values (displacement or acceleration) to correlate with peak stresses. Measurements taken in terms of rms vibration cannot be reliably correlated to peak values due to the quasi-random nature of pipe vibrations.	12/31/04	Johnson	Peak values were used for previous displacement acceptance criteria. New acceptance criteria for both displacement and acceleration will be based on peak values.	Yes
24	20214018	70042932	Acceptance criteria should be developed for the monitored valve components.	12/31/04	Johnson	Under development	Yes
25	20214018	70042932	Vibration monitoring data should be collected at predetermined pump speeds or power levels during power ascension up to the maximum speeds at which the RR pumps will be operated. Data should also be collected during the RHR shutdown cooling mode of operation. Data should also be collected at planned downpower evolutions to determine the effects of potential transient loading on RR and RHR system components.	12/31/04	Johnson	The system monitoring procedure is under development and will include these recommendations	Yes
26	20214019	70042933	The analytical finite element model results for the current configurations of the F060A/B and F077 valve operator assemblies have not been assessed to provide a correlation to the damage observed. This correlation should address a comparison of the observed damage, (such as gear box cover plate deformations, cover plate cap screw failure, damage to the stem extender/stem interface and internal yoke nut failure) to the analytically predicted results. .	12/31/04	Johnson	An assessment of the analytical model and observed damage is drafted and in review	Yes
27	20214019	70042933	The calculations establish that the first and second mode frequencies of the existing assembly are in the range of 94-98 HZ (F077) and 60-63 (F060A/B). Prior test data has shown that RHR branch piping has notable accelerations primarily at the 5X condition of 125 Hz. Hence the damage is likely to be associated with the modal frequencies of specific components such as the gear box cover plate. Because the primary operating pump speeds expected to be used for current operation and future EPU operation range from 1300 to 1600 RPM, the criteria for the modification should based on 150 HZ or greater.	12/31/04	Johnson	The valve subcomponents have been designed for the accelerations that are expected in the EPU operating range.	Yes
28	20214019	70042933	The stated action to be taken for Operation 0150 is to include sufficient post mod testing to ensure goals are met. At this time what is a "sufficient testing" has not been defined. It is recommended that post mod testing of the manual gate valve top works should include collection of vibration data including collection of data at pump speeds above 1500 RPM.	12/31/04	Johnson	The system monitoring procedure will include collecting data above 1510 RPM.	No

"B" Reactor Recirculation Pump
Action 9 SL recommendations status

Item	Notification	Order	Description	Due	Owner	Status	Restart
29	20214019	70042933	Repetitive failures of yoke nuts have been established (valve F060A, F077). It is recommended that the failure of these components should be addressed in the recommended failure mode assessment.	12/31/04	Johnson	The yoke nuts have been included in the assessment of analysis and damage.	Yes
30	20214019	70042933	It is recommended that a disassembled valve inspection should be done to conclusively determine the current condition of the F050A/F060A valve internals. If indications are noted for the F060A valve, a similar inspection of valve F060B should be conducted. The proposed radiograph would only provide an indication of gross damage and general condition and would not be expected to yield indications of loose connections	12/31/04	Johnson	F050B operator inspection was performed and the results were satisfactory. F060A operator inspection is complete. The operator was replaced due to worn stem nut. The F050A, F060B and F077 inspections are yet to be completed in RF12. The valve internals are not being inspected this outage.	Yes
31	20214020	70042934	The current plan states that noise monitoring will be conducted during power ascension. Component degradation does not generally start for weeks to months into the operating cycle. It is recommended that the monitoring system should be available and/ or the program implemented, as needed, during the full operating cycle.	12/31/04	Johnson	A detailed monitoring plan will be in place prior to plant startup. A draft plan has been developed	Yes
32	20214019	70042933	During the spring 2004 outage, modification to repair the failed cylinder of valve F050A included replacement of like for like parts. Initial walk down conducted during RF12 note indications that the actuator cylinder exhibits play. Therefore, there is reason to believe that these components will continue to fail if simply replaced. It is recommended that valve operator should be modified during RF 12.	12/31/04	Johnson	The F050A valve actuator is being inspected in this refueling outage	Yes
33	20214019	70042933	The inspection activity task for inspection of valves similar in design to F050A should define the specific attributes to be inspected. General instructions such as "visual inspection" may not be sufficient to address the intent of the inspection. Both Design Engineering and the responsible discipline engineer should contribute to the planned inspection instructions.	12/31/04	Johnson	The intent of inspection was to confirm there was no looseness of the valve actuators. This inspection was completed. No looseness was found.	Yes
34	20214041	70042935	It is recommended that the small bore connection noted by radiography with a weld anomaly be included in the ISI program for continued augmented radiographic examination at each outage until system vibration issues are resolved.	Complete	Treston	Small bore lines in question are augmented to the ISI Program for plant life.	Yes

"B" Reactor Recirculation Pump
Action 9 SL recommendations status

Item	Notification	Order	Description	Due	Owner	Status	Restart
35	20214041	70042935	It is recommended that each small bore connection to the RHR system in the vicinity of the areas of the past pipe and equipment failures, be examined with surface and visual examination at each outage until system vibration issues are resolved.	Complete	Treston	Small bore connections to the RHR system in the vicinity of the areas of the past pipe and equipment failures will be examined with surface and visual examination at each outage until system vibration issues are resolved.	Yes

'B' Reactor Recirculation Pump
NRC Questions 12/24/04

1) What is the basis for the crack propagation time?

Response:

A thermal shaft crack, which is being propagated beyond the thermal crack arresting depth by elevated mechanical loading, is not immediately apparent by shaft vibration. As the crack becomes larger, it eventually becomes detectable by vibration monitoring.

Available operating experience indicates:

In 1986, a reactor coolant pump shaft failed at a PWR (Crystal River). In this event, the station did not have pump vibration instrumentation and received no indication of the impending shaft failure.

In 1989, a reactor coolant pump shaft failed at a PWR (Crystal River). In this event, the station's vibration instrumentation detected a crack in the shaft three months prior to the failure.

In 1989, a 3rd Generation reactor recirculation pump shaft crack (Grand Gulf) was not observed by the station's vibration monitoring program until the vibration alarm was received in the control room.

In 1990, another 3rd Generation reactor recirculation pump shaft cracked. (Grand Gulf) Changes in the phase angles of the vibration data were noted three days prior to the overall vibration levels reaching the point where the pump was manually secured.

In 1996, a reactor coolant pump shaft cracked at a PWR (Palo Verde). In this event, the engineers observed an increase in the 1X and 2X vibration readings, and a steady change in the 1X phase angle. These parameters were trended for 32 days before the predetermined maximum vibration level was reached and the pump was removed from service.

In 2000, a reactor coolant pump shaft cracked at a PWR (Sequoyah). In this event, an increasing vibration trend was noticed in August (8.5 mils), and the pump was not removed from service until October (20 mils).

'B' Reactor Recirculation Pump
NRC Questions 12/24/04

2) Is bi-weekly monitoring frequent enough?

Response:

The estimated time interval between when a crack has propagated to the point where it can be detected by vibrations and when the shaft fails is estimated to be 2-3 weeks based on industry experience. In order to raise the level of conservatism the monitoring frequency will be revised to be continuous before restart from RF12. It should be noted, however, there have been no 1^{st} or 2^{nd} Generation reactor recirculation pump shaft cracks that have propagated to failure.

3) What is the technical basis of the action limits of attachment 1?

Response:

Attachment 1 [See Enclosure 2] contained two sets of action limits.

(1) Overall vibration levels used by the Operators as part of continual vibration monitoring and contained in Operations procedures.
(2) 1X and 2X vibration peaks used by the Engineers as part of in service vibration monitoring that are contained in the Engineering Monitoring procedure.

The first set of action limits were for overall vibration levels, which are alarmed in the control room. The bases for these setpoints are documented in engineering calculation SC-BB-0522 and NUCR 70043561, and are summarized below.

'B' Reactor Recirculation Pump
NRC Questions 12/24/04

Vibration Level	Parameter	Basis
7 mils	Motor vibration alarm	Eng Calc SC-BB-0522 (Under revision) The previous four years of vibration history was reviewed (1-2 mils for 'A' & 5-6 mils for 'B'). The alarm will be set slightly above the normal vibration level for 'B' Rx Recirculation pump motor (7 mils).
13 mils	Motor vibration danger limit	Eng Calc SC-BB-0522 (Under revision) The Hydraulic Institute Standards recommends vibration spikes be limited to 0.7g. 0.7g was determined to be equal to 17 mils 17 mils - 4 mils (Instrument uncertainty) 13 mils
11 mils	Pump vibration alarm	Eng Calc SC-BB-0522 (Under revision) The Hydraulic Institute Standards recommends setting vibration alarm at 2/3 the vendor limit. 25 mils (vendor limit) * 2/3 = 17 mils 17 mils - 4 mils (Instrument uncertainty) 13 mils - 2 mils (Conservatism) 11 mils
16 mils	Pump vibration danger limit	Eng Calc SC-BB-0522 (Under revision) 25 mils (Vendor Limit) - 4 mils (Instrument uncertainty) 21 mils NUCR 70043561 The pump danger limit was lowered to 16 mils to provide additional conservatism due to the industry shaft cracking concern.
25 mils	Vendor pump vibration limit	Flowserve TechNote 9309-08-022

The second set of action limits were for the specific vibration peaks and phase angles. Each of the setpoints was developed using criteria obtained from ASME OM-5/G-2003 Standard for Determining 1X and 2X Vector Acceptance Regions, and historical vibration data collected during Cycle 12 (April 2003-November 2004) specific to A and B Hope Creek Reactor Recirculation Pumps.

'B' Reactor Recirculation Pump
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The acceptance regions are based on the following formula:

$$Accept = \left(\frac{\max+\min}{2}\right) \pm 1.5 * (\max - \min)$$

Example: The 'A' Reactor Recirculation pump 1X vibration peak and phase angle in the Y direction.

Raw Data: Data collected during Cycle 12

Amplitude	Phase Angle	
2.86 mils	209°	
2.87 mils	212°	By inspection:
2.82 mils	212°	
2.68 mils	211°	The max. phase angle 212°
1.85 mils	211°	The min. phase angle 209°
2.64 mils	211°	
2.69 mils	212°	The max. amplitude 2.87 mils
2.76 mils	211°	The min. amplitude 1.85 mils
2.74 mils	211°	
2.72 mils	210°	

Phase Angle Accept = (212 + 209)/2 $\pm$ 1.5 * (212 - 209)

210.5 $\pm$ 4.5

= 206° - 215°

The OM-5 standard recommends round down the min. and up the max. to the closest multiple of 15°; therefore, resulting in the listed acceptance band of 195° - 225°

Amplitude Accept = (2.87 + 1.85)/2 $\pm$ 1.5 * (2.87 - 1.85)

2.36 $\pm$ 1.53

= 0.8 - 3.9

'B' Reactor Recirculation Pump
NRC Questions 12/24/04

4) The action levels do not appear to be specific enough.

Response:

Attachment 1 [See Enclosure 2] contained two sets of action limits and required actions.

(1) Overall vibration levels required actions used by the Operators to take immediate actions as outlined in various operating procedures.
(2) 1X and 2X vibration peaks required actions used by the Engineers as part of in-service vibration monitoring evaluation. These actions are used by the engineers to develop their reactor recirculation pump operation recommendations to the operators.

The following table is a summary of the various vibration actions limits and associated required actions.

Limit	Parameter	Required Actions
7 mils	Motor vibration alarm	1) Lower pump speed to lower vibration level IAW with HC.OP-AB.RPV-0003. (See Note 1 below) 2) If vibration levels do not lower below 7 mils remove pump from service IAW the normal operating procedure HC.OP-SO.BB-0002.
13 mils	Motor vibration danger limit	Remove pump from service IAW the normal operating procedure HC.OP-SO.BB-0002.
11 mils	Pump vibration alarm	1) Lower pump speed to lower vibration level IAW with HC.OP-AB.RPV-0003. (See Note 1 below) 2) If vibration levels do not lower below 11 mils remove pump from service IAW the normal operating procedure HC.OP-SO.BB-0002.
16 mils	Pump vibration danger limit	Remove pump from service IAW the normal operating procedure HC.OP-SO.BB-0002.

'B' Reactor Recirculation Pump
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Limit	Parameter	Required Actions
Varies	1X and 2X vibration peak amplitude	1) Immediate review of data by Component Eng. with recommendations to operations: (See Note 2 below) (a) Remove pump from service. (b) Continue operations with increased monitoring frequency. (c) Continue operations and acceptance band will be revised. 2) Initiate Notification
Varies	1X and 2X vibration peak phase angle	1) Immediate review of data by Component Eng. with recommendations to operations: (see note below) (a) Remove pump from service. (b) If amplitude is high decrease pump speed. (c) Continue operations with increased monitoring frequency. (d) Continue operations and acceptance band will be revised. 2) Initiate Notification

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Note 1: From Step K of HC.OP-AB.RPV-0003:

K.1 **REDUCE** Recirc. Pump Speed as required to maintain vibrations below the ALERT limit as follows:

A. **ENSURE** the following controllers are in MANUAL:

- SIC-R621A PUMP A SPD CONT
- SIC-R621B PUMP B SPD CONT

B. **RECORD** affected pump speed in the Control Room Logs.

☆ **CAUTION 6** ☆

C. **MAINTAIN** the affected Pump ALERT limit clear as follows:

'B' Reactor Recirculation Pump
NRC Questions 12/24/04

- INTERMITTENTLY **PRESS** SIC-R621A(B) PUMP A(B) SPD CONT DECREASE push button on the affected Recirculation Pump.
- **INSERT** Control Rods as required by Reactor Engineering Instructions.

K.2 IF ALERT limit cannot be maintained clear AND the affected Recirculation Pump Speed has been lowered by ≥20% (compare to value logged in Step K.1.B), THEN **REMOVE** the affected Recirc Pump from service IAW HC.OP-SO.BB-0002, Single Loop Operation.

K.3 IF the vibration DANGER Limit comes into alarm, THEN **TRIP** the affected Recirc Pump AND **EXECUTE** Condition A of this procedure.

Note 2: Engineering will review a series of data, which will be outlined in procedure HC.ER-AP.BB-0001 (procedure to be issued before restart from RF12). That data includes:

1) Past trend of the data point which is out of its acceptance band.
2) Recent maintenance history of pump.
3) Other pump factors such as pump speed, RACs temperature, RCS pressure.
4) Expected precursors of a cracked shaft.

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5) What is technical basis for the location of the monitoring equipment on the pump?

Response:

The Hope Creek Reactor Recirculation pump vibration levels are monitored by two proximity probes (X and Y direction). The proximity probes on 'A' Reactor Recirculation pump are located on the lower flange of the coupling spool piece. The proximity probe on 'B' Reactor Recirculation pump is located on the upper flange on the pump half coupling. The probes were not part of the original Flowserve design of the reactor recirculation pumps. Vibration monitoring equipment was not prevalent at the time of the pump's original design. The proximity probes were added during the initial installation of the reactor recirculation pumps. This is comparable to industry experience.

'B' Reactor Recirculation Pump
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The most accurate location to detect pump vibration instrumentation is directly off the pump shaft. Installing vibration instrumentation as close to the impeller as practical can further increase accuracy. Since the reactor recirculation pumps are vertical pumps, there is only a limited amount of exposed shaft available to attach the proximity probes. The preferred location is the lower flange of the coupling spool piece. This surface is trued to the rotational centerline of the complete pump assembly as part of the initial coupling stackup; therefore, it would be a true reading of shaft vibration rather than inaccuracies from roundness or eccentricity of a non-trued surface. The upper flange of the pump half coupling would be a reasonable alternative, as it was typically trued to the element centerline as well.

Information provided to NRC in response to HPCI and Recirc issues

Docket	Document ID	Revision	Title	Source
PSEG Documents				
yes	H-1-BB-MEE-1878	Rev 0 12/12/2004	HC "B" Recirculation Pump Vibration Analysis	
yes	H-1-BB-MEE-1878	Rev 1 12/16/2004	HC "B" Recirculation Pump Vibration Analysis	ENCLOSED
yes	H-1-BB-CEE-1830	Rev 2 4/5/2004	Evaluation of Hope Creek In-Drywell Pipe Vibration	
yes	H-1-BB-CEE-1862 (CR 70037702).	Rev 0 10/26/2004	Hope Creek Recirc/RHR Pipe Vibration - Common Cause Evaluation	
yes	H-1-FD-CEE-1879	12/12/2004	HC HPCI Exhaust Piping Supports Analysis Reported Damage in RF12	
yes	GMHC-97-021	6/12/1997	Mark Bezella Letter: Reactor Recirculation Pump Shaft and Cover Related Decision	
yes	HC-OP-AR.ZZ-0008(Q)	Rev 25A (10/30/2004)	Overhead Annunciator Window Box C1, Operations Alarm Response Procedure	
yes	HC.OP-SO.BB-0002(Q)	Rev 50A (10/30/2004)	Reactor Recirculation System Operating Procedure	
yes	SC-0270	12/13/2004	Bending Evaluation of Snubbers for support 1-P-FD-006-H20	
yes	SC-BB-0522	1/13/2004	Loop Tolerance Calculation for 1BBVSH-7910A1-A2-A4-B1-B4	
yes	C-0031	9/7/2004	Piping Code Compliance	
yes	H1BC-1-BC-V183	11/8/2004	Handwheel OP Spins Freely	
yes	H-1-BB-MEE-1050	12/26/1995	Hope Creek Recirculation system Large Bore Pipe Cracking Resolution	
yes	M-13-1		P&ID, Reactor Auxiliaries Cooling System	
yes	M-43-1		P&ID, Reactor Recirculation System	
yes	DCP 80062466	8/23/2004	EPU Piping Vibration Monitoring Installation Package	
yes	DCP 80062466	Rev 1 10/19/2004	EPU Piping Vibration Monitoring Installation Package	
yes	DCP 80062466 (Final)	Rev 2 12/10/2004	EPU Piping Vibration Monitoring Installation Package	
yes	ECP 4EO-3507 pkg 3	8/27/1997	Equivalent Change Package for Snubbers	
yes	E-mail	10/22/1999	Hope Creek "B" Reactor Recirc. Pump Vibration	

Docket	Document ID	Revision	Title	Source
yes	Rpt No. 71125	6/3/1987	Transient & Steady State Analysis of the 1AP and 1BP Reactor Recirculation Pumps, Hope Creek	
yes	Seal History	3/12/1992	Recirc Seal History	
yes	CR 20015425	12/14/1999	"B" Recirc Pumps Seal Root Cause Info.	
yes	WO 970915562		Snubber Functional Testing	
No	Notes	11/3/2004	Interview Notes from Mr. Flanagan on "B" RR Pump	
yes	Overview	NA	Summary of Hope Creek Vibration Issues and Planned Actions	
yes	Summary	NA	"B" Reactor Recirculation Pump Vibration Troubleshooting Summary	
yes	Summary	NA	"B" Reactor Recirculation Pump Stuffing Box Measurements Summary	
yes	CR 70029861	3/1/2003	HC "B" Recic Pump Excessive Seal Leakage - Condition Report	
yes	Summary		Component History search results *FD-006-H022	
		External Documents		
yes	ER-VR04-0752	12/23/2004	Evaluation of Reservoir isolation valves for 307256 snubbers returned from PSE&G.	Lisega
yes	270		Tech Bulletin - Early Crack Detection on Rotating Machinery	Bently Nevada
yes	Orbit Magazine	Dec-90	Reactor Recirculation Pump Shaft Crack	
yes	HC-06-301	11/3/2004	Hope Creek Recirculation System Vibration Testing (VTD 326747)	Structural Integrity Assc. Inc.
No	0000-0027-4832-01	4/29/2004	Recirculation & RHR Startup Test Criteria (VTD 326534)	GE Nuclear
Yes	RAL-7482	Rev 0 10/26/2004	Design Modification Report Assy 93-15122	Flow Serve
Yes	RAL-7483	Rev 0 10/26/2004	Design Modification Report Assy 93-14347	Flow Serve
Yes	040555BP	6/16/2004	Vibration Testing of Recirc. And RHR Piping Instrumentation (VTD 326560)	VibrAlign
No	9309-08-022	NA	Reactor Coolant Pumps Shaft Vibration Limits	Flow Serve
No	IE-3429-4	4/11/1994	Tech Manual for Reactor Coolant Pump (selected material)	BJ Pump Division
yes	HC-04Q-301	4/29/2004	Hope Creek Extended Power Uprate Piping Vibration Monitoring	Structural Integrity Inc.
yes	ASME ICON 4	Mar-96	An Advanced Design Main Coolant Pump for BWR Plants, S. Gopalakrishnan, BW/IP International Pump Division,	

Docket	Document ID	Revision	Title	Source
yes	Pumpentagung Pump Congress	Oct-92	Analytical Investigation of Thermal Cracking in Reactor Recirculating Pumps, S. Gopalakrishnan, BW/IP International Pump Division,	
yes			Crack Propagation in Main Coolant Pumps, S. Gopalakrishnan, BW/IP International Pump Division	
Subject to Export Control	TR-100154	Feb-92	Evaluation of Main Coolant Pump Shaft Cracking	EPRI
yes		12/15/1987	GE SIL 459	General Electric
yes		3/23/1990	GE SIL 459S1	General Electric
yes		10/21/1991	GE SIL 459S2	General Electric
yes		8/31/1993	GE SIL 459S3	General Electric
yes	OE 3351	5/11/1989	Grand Gulf 1 Shaft Failure	
yes	OE 3365	5/23/1989	Grand Gulf 1 Shaft Failure	
yes	OE 3557	9/20/1989	Grand Gulf 1 Shaft Failure	
yes		11/12/2004	Independent Assessment of Reactor Recirculation System and Pump Vibration Issues,	Sargent & Lundy
yes	VTD PN1-B31-C001-0124		Reactor Recirculation Pump Dwg	BJ Pump Division
no	10855-D-3.38	Rev 9 5/23/2000	Design Installation and Test Spec for HPCI System	Bechtel
no	10855-M-068(Q)	Rev 16 9/25/1996	Design Specification for Nuclear Power Piping ASME Section III, Class 2 and 3	Bechtel