Hope Creek Recirc/RHR Pipe Vibration Common Cause Analysis

EXECUTIVE SUMMARY

On March 13, 2004 an unusual banging noise, reportedly coming from inside containment, was heard by Hope Creek plant personnel entering the north pipe chase. When the plant was subsequently shutdown, containment walkdowns revealed a number of degraded conditions inside containment, primarily on the RHR return lines that connect to the recirculation piping main loops. The degraded conditions were thought to have resulted from vibration of the recirculation and RHR piping during operation. This common cause analysis report summarizes results of investigations into the cause of the vibration and the resulting degradation, and the noise heard in the pipe chase.

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

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

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

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

The effect of this vibration has been to cause degradation of components in the RHR piping inside containment; specifically, hardware connected to certain RHR valves. This report also explores the individual degraded conditions that stem from this common cause.

The report finds that the common cause of the current and past degradation observed at the plant results from equipment being subjected to pump-induced pressure pulsations at frequencies at or near equipment structural resonances. This results in vibratory loads on the equipment which over time cause the equipment to degrade due to high cycle wear, fretting or fatigue. The fact that the installed plant equipment has structural resonances at or near the expected pump pulsation frequency ranges indicates that the original plant design did not guard against this possibility. It is noted that due to the variable speed operation of the recirculation pumps, and

the wide range of speeds at which they operate, makes it difficult to design equipment with natural frequencies that will not be excited by the wide range of expected pulsation frequencies.

An earlier effort to determine the source of the noise heard in March 2004 determined that the noise originated either from a detached air piston cylinder associated with a check valve in the RHR piping inside containment, or possibly from a loose handwheel on an adjacent block valve. Both of these conditions were fixed prior to restarting the plant in April 2004. However, in May 2004 the noise returned. Accordingly, at this time the cause of the noise has not been positively ascertained. The report investigates possible causes and provides recommendations for validating the actual cause.

Table of Contents

1 REVISION SUMMARY

Revision	Date	Description
0	July 27, 2004	Original Issue.

2 PURPOSE

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

Notification 20182421was written to identify that multiple, likely related, degraded conditions were discovered and to request an analysis to determine the cause(s) of the degradation and to determine necessary corrective actions. This engineering evaluation was prepared to determine the common cause(s) of degraded conditions and provide recommendations for corrective actions.

3 SCOPE

The scope of this evaluation is the degraded conditions documented in Notification 20182421. This includes:

- The extent of condition evaluation for the vibration of the large bore recirculation and RHR piping inside containment.
- The degraded conditions discovered in March 2004 on the portions of the residual heat removal (RHR) piping connected to the recirculation system inside the Hope Creek containment.
- The noise heard in the north pipe chase in March 2004 (and later in May 2004).

4 DISCUSSION

4.1 Background

4.1.1 System Configuration

Hope Creek has two reactor recirculation system (RRS) pumps that provide drive flow to the 20 jet pumps in the reactor vessel. Each RRS pump takes suction from the annulus of the reactor vessel and discharges into a header that feeds ten jet pumps. The RRS pumps are equipped with motor-generator sets that permit the pumps to run at varying speeds. By varying the speed of the pumps, the drive flow to the jet pumps can be varied, which in turn changes the flow rate (and hence temperature and quality) of water and steam passing through the core. Since the moderation of the nuclear reaction is dependent on the water temperature and steam quality in the core, varying the RRS pump speed in effect can be used to control core power.

Figures 4-1 and 4-2 show the configuration of the recirculation and RHR piping inside containment. There is a single RHR supply line connecting to the recirculation piping "B" loop pump suction. This 20 inch diameter line is the supply flow from the recirculation system to the RHR heat exchangers outside containment. Between the recirculation loop and containment penetration, there are two gate valves, one midway and one at the containment penetration.

There are two RHR return lines connecting to the recirculation pump discharge lines, one line to each loop. Between the recirculation pump discharge line and the containment penetration, the RHR return lines each contain a manual gate valve (normally locked open) and a testable check valve. The check valves allow flow into the recirculation piping from the RHR system. There is also a normally closed containment isolation valve just outside containment on each RHR return line.

The major components in the recirculation system and RHR system piping involved in this evaluation are listed in Table 4-1.

Table 4-1. Major Recirculation and RHR System Components

Component	Description
Valves 1BCHV-F050A, 1BCHV-F050B	Testable check valves in RHR return lines. Prevent backflow from recirculation system into RHR system outside containment. Also containment isolation valves for the RHR return line penetrations.
Valves 1BCHV-F060A, 1BCHV-F060B	Locked open, manual gate valves in RHR return lines, located between F050 valve and recirculation piping connection. Used to isolate the testable check valves from the recirculation system for maintenance or test.
Valves 1BCHV-F015A, 1BCHV-F015B	Normally closed, motor operated gate valves in the RHR return lines, outside the containment penetration. Containment isolation valves for the RHR return line penetrations.
Valve 1BC-HV-F008	Normally closed, motor operated gate valve in the RHR supply line, outside the containment penetration. Containment isolation valve for the RHR supply line penetration.
Valve 1BC-HV-F009	Normally closed, motor operated gate valve in the RHR supply line, inside containment. Opened when RHR supply flow is needed.
Valve 1BC-HV-F077	Locked open, manual gate valve in RHR supply line, located between F009 valve and recirculation piping connection. Used to isolate F009 from the recirculation system for maintenance or test.
Valve 1BB-HV-F031A, 1BB-HV-F031B	Normally open, motor operated gate valves on the recirculation pump discharge lines.
Valve 1BB-HV-F023A, 1BB-HV-F023B	Normally open, motor operated gate valves on the recirculation pump suction lines.
Pumps 1A-P-201, 1B-P-201	Variable speed reactor recirculation pumps.
Containment Penetrations P4A, P4B	Containment penetrations for the RHR return lines.
Containment Penetration P3	Containment penetration for the RHR supply line.

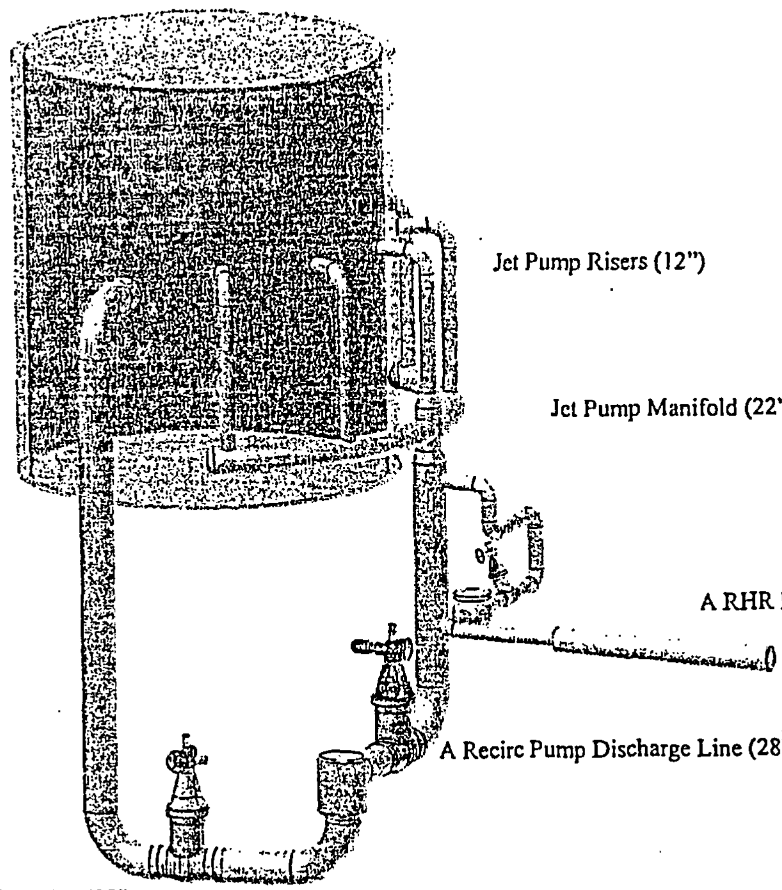


Figure 4-1
Recirculation and RHR Return Piping Inside the Drywell
Loop A

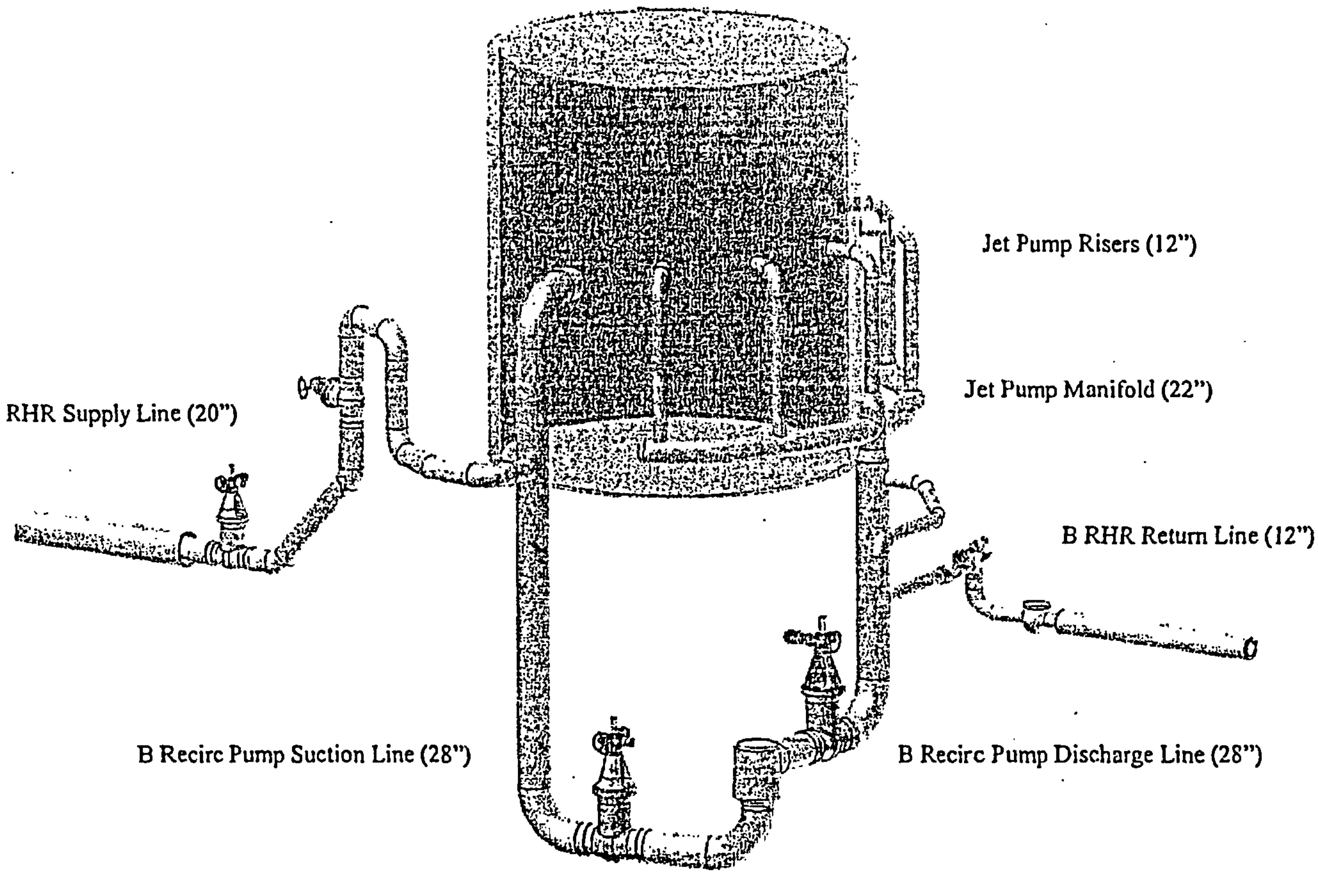


Figure 4-2
Recirculation and RHR Supply and Return Piping Inside the Drywell
Loop B

4.1.2 Pressure Fluctuations Applied to Piping

The recirculation and RHR piping is subject to pressure fluctuations resulting from the recirculation pump rotation. These include pressure fluctuations at the pump running speed (known as 1X fluctuations), and fluctuations occurring as the vanes of the impellers pass the flow passages in the pump casing. There are five vanes in the Hope Creek recirculation pump impellers, so each rotation of the pump results in five pressure fluctuations. These fluctuations are referred to as 5X fluctuations. As the pump speed changes, the frequency of these fluctuations also changes, as summarized below for the range of pump speeds seen during the current operating cycle:

Typical Pump Running Speed Range	Fluctuation Frequency at 1X (pump running speed)	Fluctuation Frequency at 5X (pump vane passing frequency)
Low Speed 450 rpm	7.5 Hz	37.5 Hz
High Speed 1500 rpm	25 Hz	125 Hz

In addition, pressure fluctuations can occur at higher multiples of these speeds. For example, Figure 4-3 below shows the measured vibration accelerations at a point on the Loop B recirculation piping when the Loop B pump was operating at 460 rpm. At this pump speed, the 1X frequency is 7.7 Hz and the 5X frequency is 38.3 Hz. The piping response at these frequencies is clearly evident. The figure shows there are also smaller but noticeable responses (peaks) at the following frequencies:

- Multiples of the pump running speed: 2X (15.3 Hz), 3X (23 Hz), 4X (30.7 Hz), 6X (46.0 Hz), and so on.
- Multiples of the vane passing frequency: 5X (38.3 Hz), 10X (76.7 Hz), 15X (115.0 Hz), and 20X (153.3 Hz).

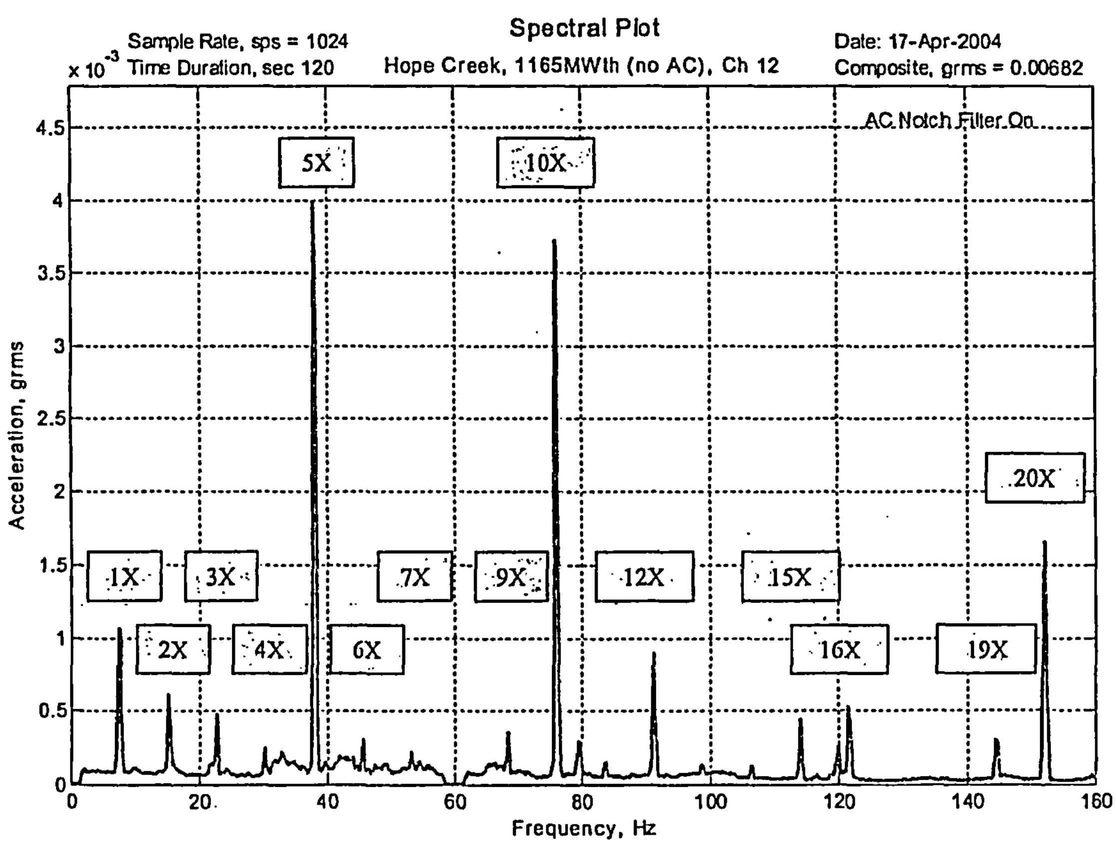


Figure 4-3
Typical Vibration Accelerations with Pump Speed of 460 rpm

Accordingly, pressure fluctuations occur during operation at various power levels at frequencies ranging from 7.5-25 Hz due to the pump running speed, and from 37.5-125 Hz due to the pump vane passing frequency; and at integer multiples of these frequencies. Vibration monitoring during plant startup and during the first few operating cycles showed that these pressure fluctuations cause motion of the recirculation and RHR piping.

4.1.3 Effect of Piping System Configuration on its Response to Pressure Fluctuations

The response of the piping system and individual attached components to the pressure fluctuations occurring in the recirculation system is a function of the piping system geometry. There are two main considerations, as follows:

- The piping system itself, and the attached hardware components, have structural resonances that are functions of the size, mass, configuration, and material properties of the system elements. If the system or components are subjected to cyclic loads occurring at or near these structural resonances, the response of the system or components can be greatly amplified. This is a major concern for systems affecting safe plant operation (like the Hope Creek recirculation and RHR systems), which must be designed to withstand seismic events. For these piping systems, designers take care to place piping supports so as to "tune" the piping structural resonances so that the response of the system cyclic loads imposed by earthquakes is acceptably small. For components, designers generally try to ensure that the component structural resonances are much higher than the highest seismic cyclic load of concern (generally considered to be 33 Hz in the nuclear industry). By so doing the cyclic loads are not amplified. Of particular note: the 5X pressure pulsation frequencies discussed above occur at much higher frequencies than this 33 Hz upper bound seismic frequency. Accordingly, piping and components designed to withstand seismic loading by ensuring that their structural resonances occur at frequencies higher than 33 Hz are not necessarily designed with the 5X (and higher multiple) pump vane passing frequencies in mind. This is not considered to be a problem for seismic loads because displacements at the higher frequencies are generally very small, and for seismic loads the number of cycles expected to occur during the plant life is relatively few as well.

  As discussed later in this report, the recirculation and RHR piping system structural resonances have been calculated for Hope Creek in Reference 7. In addition, structural analyses exist for several of the components in the system that document the acceptability of these components for seismic loads.

- The piping system has acoustic resonances that are functions of the pipe lengths and the speed of sound of the media (subcooled water, in the case of recirculation and RHR piping) they carry. If the piping system is excited by a pressure pulsation at its acoustic resonance frequency, then the response of the system to the pressure pulsations can be greatly amplified. This amplification occurs when the wavelength of the pressure pulsation matches certain multiples of the piping length between boundary points. Acoustic resonances can be detected by applying a cyclic pressure pulsation somewhere in the system and monitoring the resulting pressure pulsations elsewhere in the system. As the applied pressure pulsation varies in frequency, the wave length of the pulsation will approach or recede from various multiples of the piping length. At the acoustic resonance frequency, the response to the pulsation will be amplified to some extent. Note that the speed of sound in water is a strong function of temperature and pressure; minor changes in these parameters can cause significant changes in the speed of sound, and hence the system acoustic resonances.

Currently there is no acoustic model of the Hope Creek piping system, so the presence of acoustic resonances in the pump vane passing frequency has not been definitively determined. This report will address the potential that acoustic resonances exist that are contributing to the degradation observed at Hope Creek.

4.2 Degraded Conditions Discovered in March 2004

The containment walkdowns during the March 2004 forced outage discovered a number of degraded conditions. These conditions are summarized in Table 4-2. Attachment A provides photographs taken of degraded equipment during March and April 2004. Descriptions of the banging noise that was heard in the north pipe chase, and the other observed conditions discovered in the ensuing outage, are provided below.

- On March 13, 2004, prior to plant shutdown, plant personnel reported hearing a "banging" noise coming from inside containment when they were in the north pipe chase. Investigation performed following this observation determined that the banging noise was likely coming from the loop "A" RHR return line, in the vicinity of the 1BC-HV-F050A and 1BC-HV-F060A valves. This line penetrates containment in the north pipe chase.

- The hand wheel had fallen off of valve 1BC-HV-F060B. This is a manual block valve located inboard of the testable check valve 1BC-HV-F050B in the "B" loop RHR return line. (Note, this line does not communicate with the north pipe chase.) The handwheel was found suspended from its lockwire near the manual valve operator where it had previously been attached. The hub on the operator shaft was found to be worn and the retaining ring meant to hold the handwheel on the hub was missing.

- The air piston cylinder for the actuator on testable check valve 1BC-HV-F050A was found to be disconnected from the actuator assembly. The cylinder is normally fastened to the actuator assembly with a threaded connection and held in place with a set screw.

- Limit switches were found to have failed on the 1BC-HV-F060A and 1BC-HV-F060B valves in containment. These valves are located on the RHR return piping lines near where they connect to the recirculation discharge piping. In addition, the limit switch on valve 1BC-HV-F065D was also found to be close to the edge of its indicating finger.

Two other conditions were noted in this outage that are not addressed in this analysis:

- Notification 20182454 stated that the bellows encapsulation sleeve around Penetration P4B was loose. This is as designed; the sleeve must be loose to allow the expansion joint to change in length with temperature. Accordingly, there is no indication of degradation at this sleeve.
- Notification 20182505 stated that small bore pipe H1BB-1-P-BB-044 had wear marks indicating possible movement of 1-2 inches. This pipe is an instrument line from the reactor pressure vessel to valve XV-372. This line is not connected to the recirculation or RHR lines and is therefore not included in this scope.
- Notification 20182394 stated that the limit switch for valve H1BC-1BCZS-F065 was found to be incorrectly aligned. Specifically, the notification states that the limit switch was found to be off the switch finger plate. This line does not connect directly to the recirculation system or to the RHR supply/return piping attached to the recirculation system, and is therefore not included in this scope.

Table 4-2. Degraded Conditions Found in March 2004 Forced Outage

Notification	Description	Component / Location
20182421	Piping is experiencing a vibration condition that causes a metal to metal noise within the drywell. The noise is audible in the north pipe chase.	H1BB
20182400	The handwheel on the F060B B RHR return valve was discovered to have fallen off the valve.	H1BC-1BCZS-F060B
20182396	The limit switch actuator arm and rod for valve F060A are broken and missing.	H1BC-1BCZS-F060A
20182395	The limit switch actuator arm and rod for valve F060B are broken.	H1BC-1BCZS-F060B
20182394	The limit switch alignment for valve F065D (LPCI injection line D manual valve) is not correct for the open limit. The limit is off the edge of the striker plate.	H1BC-1BCZS-F065D-E11
20182397	The actuator mechanism on valve F050A has come apart. The cylinder surrounding the air piston has dropped about 4 inches and is not functional.	H1BC-BC-HV-F050A
20182505	The saddle pipe restraint was very tight and there were indications that the pipe is moving 1-2 inches, evidenced by wear marks on the pipe.	H1BB-1-P-BB-044-H001

5 COMMON CAUSE ANALYSIS PROCESS

5.1 Scope

This common cause analysis will address the following issues identified in March 2004 that are thought to be related to the vibration of the recirculation and RHR piping:

- Degradation to limit switches for valves F060A and F060B;
- Degradation to the handwheel on valve F060B;
- Degradation to the actuator for valve F050A;
- The noise heard in the north pipe chase in March 2004.

To perform this common cause analysis it will be necessary to understand the piping vibration in the affected systems, and past experience with vibration and related degradation.

5.2 Problem Statement

On March 13, 2004, an unusual banging noise, reportedly coming from inside the Hope Creek containment, was heard by PSEG Nuclear personnel entering the north pipe chase. At the time the plant was operating at full power. The plant was subsequently shutdown for an unrelated issue. During a containment inspection performed while in shutdown, inspectors identified a number of degraded conditions inside containment, primarily on the RHR return lines that connect to the recirculation piping main loops. The degraded conditions were thought to have resulted from vibration of the piping during operation. As described in detail later in this report, some of the degraded conditions have occurred previously in the plant history (limit switch failures and handwheel detachment); others, such as the detachment of the F050A actuator and the noise in the north pipe chase, may not have occurred previously.

5.3 Data Collection

5.3.1 Data Sources

Data sources reviewed include the following:

- Equipment history information (notifications, CRs, maintenance records and startup deviation reports)
- Previous evaluations of vibration-related issues (engineering evaluations and calculations)
- Industry experience (from INPO and NRC databases)
- Vendor and consultant experience (from General Electric, Structural Integrity Associates and MPR Associates)

- Equipment suppliers
- Plant operating data, from computer logs, completed procedures and narratives, for the cycle preceding the March 2004 forced outage
- Personnel statements and interviews
- Completed surveillance tests
- Structural analysis of certain components
- Photographs of degraded conditions
- Vendor technical documents
- Metallurgical analysis of the failed limit switch from valve F060A
- Vibration data from prior testing (original startup testing and testing performed during root cause analysis of small bore line cracking)
- Personal contacts with system engineer at Nine Mile Point Unit 2
- ASME code calculations and seismic qualification calculations for affected system valves

In addition to these data sources, it was necessary in this effort to obtain additional data on current pipe vibration that was not otherwise available. This was accomplished by installing temporary acceleration monitoring equipment to determine the magnitude and frequency of pipe vibrations, and implementing a test plan to obtain vibration measurements at varying plant operating conditions.

5.3.2 Data Review

To aid in completing the common cause analysis, subject matter experts from the following companies and divisions were consulted:

- General Electric
- MPR Associates
- PSEG Maplewood Labs
- PSEG Nuclear Components Group personnel
- PSEG Nuclear Design Engineering personnel
- PSEG Nuclear Operations Department personnel (at Hope Creek)
- Structural Integrity Associates
- VibrAlign

5.4 Analysis Technique Selection

PSEG Nuclear Procedure NC.CA-TM.ZZ-0003(Z), Root Cause Evaluation Guideline (Reference 1), provides guidance for performing and documenting root cause analyses, along with several recommended techniques. Using the guidance of this procedure, this analysis will use the technique of Equipment Failure Analysis. Causal factor tables are prepared for each degraded condition and provided in Attachment F.

6 COMMON CAUSE ANALYSIS

6.1 Recirculation and RHR Piping Vibration

Vibration of recirculation systems and attached piping is a well-recognized phenomenon in BWRs. The Hope Creek recirculation and RHR systems have a history of experience with vibration and attempts to monitor it and accommodate its presence. This section summarizes the plant's experience with vibration over the course of the plant life, including the results of vibration monitoring performed in Spring 2004 in part to support this common cause analysis.

Note: All tables and figures referred to in this section are provided at the end of Section 6.1 for clarity.

6.1.1 Startup Vibration Testing (1986)

Test engineers monitored vibration during original plant startup as follows:

- For the recirculation piping, test engineers monitored vibrations in a number of locations on the recirculation piping and monitored accelerations at a variety of pump speeds. Results are contained in a series of completed test procedures. Piping displacements measured during this testing were compared to displacement acceptance criteria, and found in all cases to be below the permitted maximum displacements. Table 6-1 summarizes the data collected during the startup testing.

- For the RHR return piping inside containment, Bechtel Technical Specification 10855-P-422Q (Reference 15) instructed trained test engineers to visually observe vibration and judge whether further monitoring (using hand-held vibrometers to measure velocity) was required. No record of the results of these inspections has been located to date. It is assumed that the RHR piping system vibration monitored in this way was determined to be acceptable.

6.1.2 Small Bore Line Failures Early in Plant Life (1987-1989)

During the first few operating cycles at Hope Creek, several small bore lines attached to the large bore (28" diameter) recirculation system piping experienced failures and cracking at the connection point to the large bore recirculation piping. Table 6-2 summarizes these events. Root cause analyses showed that the failures were due to vibration of the large bore piping at a frequency at or near the mechanical natural frequency of the small bore lines. The source of the vibration of the large bore lines was determined to be pressure pulsations in the lines generated as the vanes of the reactor recirculation pump impellers pass the cutwaters in the pumps. To minimize vibration and prevent fatigue damage, PSEG Nuclear modified the small bore lines on the suction elbows and on the valve drain lines by tying them back to the large bore pipe. This modification essentially stiffened the small bore lines, thereby raising their mechanical natural frequency above the vane passing frequency.

Table 6-3 summarizes the displacements recorded on the small bore lines mounted on the recirculation pump suction elbow during testing performed to verify the root cause of these small bore line failures. The data presented are from PSEG Calculation SC-0223, "Evaluation of the Post-Modification Pipe Vibration of the RR Instrumentation Lines" (Reference 2). Attachment B shows several typical frequency versus displacement plots produced during this testing. The following observations are made based on review of data collected at that time:

- The overall amplitude of the measured displacements at the recirculation pump suction elbows determined by summing the peak displacements shown in Table 6-3 is on the order of 0.002 to 0.008 inches. Algebraic summation of these displacements at varying frequencies provides a conservative estimate of the overall vibration displacement.
- The piping has significant displacement response at the pump running speed and the vane passing frequency.
- In addition to these responses, the plots show a significant amount of broad band noise centered about 23 Hz. No cause for this noise was presented in the reference calculation.

6.1.3 *Increased Vibration at High Recirculation Pump Speeds (1993)*

In October 1993 a noise described as similar to a "freight train" sound was heard coming from the Hope Creek containment. This occurred at a recirculation pump speed of 1529 rpm and a total core flow of 102.5 percent (CR951005196). The cause of this phenomenon has not been determined. PSEG Nuclear responded by changing plant operating procedure HC.OP-SO.BB-0002(Q) (Reference 3) to state that operation at over 1510 rpm should be avoided. Based on plant experience, this limit is sufficient to prevent recurrence of this phenomenon.

This condition appears to be similar to vibration that has occurred at other BWRs. For example, in 1994 Susquehanna experienced an increased vibration condition when the recirculation pumps were operated at high speeds (1580 rpm). The resulting vibration was described in NRC Information Notice 95-16 (Reference 4) and led GE to issue SIL-600 (Reference 5). GE reported that the vibration was caused by the pressure pulsations from the recirculation pumps causing acoustical resonances in the RHR return line when the check valve in the RHR line was not fully seated.

6.1.4 2001 Small Bore Line Failure

Small bore pipe line BB-321 on the Loop A suction elbow outer elbow tap failed in-service in October 2001. Root cause analysis completed at that time concluded that this line failed due to the presence of an accelerometer that was left on the pipe line following testing performed earlier in the plant life. The analysis showed that added mass of this accelerometer shifted the natural frequency of this pipe line – which had been stiffened by tying it back to the pipe – back to the range where the structure could be excited by the recirculation pump vane passing frequency. The accelerometer was removed and the line was repaired and placed back in service with no problems since.

6.1.5 Vibration Monitoring Performed in Spring 2004

Approach

PSEG Nuclear prepared Engineering Evaluation H-1-BB-CEE-1830 (Reference 6) following the discovery of damage to components in the RHR piping in March 2004. This evaluation provided the basis for restart of Hope Creek following the March 2004 forced outage. One of the recommendations of that evaluation was to monitor pipe vibration during restart.

In accordance with this recommendation, PSEG Nuclear developed a test plan for monitoring vibration inside containment. As part of the monitoring program, PSEG Nuclear installed accelerometers to measure piping vibration inside the drywell. Specifically, accelerometers were installed as follows under Temporary Modification Package 04-006:

- Accelerometers were installed on the Loop A and Loop B recirculation pump suction piping elbows upstream of the pump suction isolation valve (1BB-HV-F023A and -F023B valves). At each location, three accelerometers were mounted on horizontal piping to detect pipe accelerations in three orthogonal directions: along the pipe axis, perpendicular to the pipe axis in the horizontal direction, and in the vertical direction. These locations were selected because acceleration data was obtained at nearly the same points in 1991 as part of the root cause analysis of failures of the small bore lines attached to the same elbows. Placing accelerometers in these locations allows comparison of the current vibration to that measured in 1991, permitting determination of whether the vibration has changed in nature over the years.

- Accelerometers were installed on the Loop A and Loop B RHR return lines, near the location of the manual isolation block valves (1BCHV-F060A and -F060B valves, respectively) in these lines. At each location, three accelerometers were mounted on horizontal piping to detect pipe accelerations in three orthogonal directions: along the pipe axis, perpendicular to the pipe axis in the horizontal direction, and in the vertical direction. These locations were selected because the damage observed in March 2004 occurred at or near these valves. Measurement of vibration occurring in these locations provides data for use in the common cause analysis of the observed damage.

There are 12 accelerometer locations described above. A total of 13 accelerometer cables were available; accordingly, PSEG Nuclear opted to install a thirteenth accelerometer. The location selected for this accelerometer was the top elbow of the 12" diameter riser pipe leading to reactor nozzle N2H (which provides the drive flow for one of the jet pumps). This location was selected because analysis performed by General Electric (as described in GE Letter MRT-9527, December 15, 1995, "Task 1.1 Modal Analysis of Hope Creek Recirculation and RHR Piping," Reference 7) indicated that this location has a structural natural frequency in the range of the vane passing frequency of the jet pumps. The accelerometer was installed such that it monitored vibration in the vertical direction at this point.

The test plan for vibration monitoring required that vibration displacements be determined at each location at specified power levels during ramp-up to full power. Vibration displacements were determined by double integration of the acceleration data recorded at each power level.

Vibration Acceptance Criteria
Vibrations measured in Spring 2004 were compared to acceptance criteria developed by General Electric in document GENE -0000-0027-4832-01, DRF-0000-0027-4832, "PSEG Nuclear LLC Hope Creek Generating Station Recirculation & RHR Piping Start-Up Test Criteria," Revision 1 (VTD 326534, Reference 8). The acceptance criteria were selected to ensure that oscillating stresses resulting from vibration were below the fatigue stress limit for the piping system materials.

Data Collection
As the plant restarted following the March 2004 outage, accelerometer readings at each of the 13 accelerometers were obtained at over 30 separate occasions as the plant changed power levels. The accelerations were recorded for a 120 second time interval during each occasion. In addition, test personnel recorded plant conditions such as pump running speeds and core thermal power level.

The recorded data was transmitted electronically to Structural Integrity Associates personnel, who performed the following operations:

- Fast Fourier Transform (FFT) of the time domain acceleration data to produce FFT plots of the accelerations as a function of frequency for each accelerometer;
- Numerical integration of the acceleration data to determine the velocity profile over the time interval;
- Numerical integration of the velocity profile to determine the displacement time history;
- Review of the displacement time history to determine the maximum positive and negative displacements calculated to occur over the time interval;
- Calculation of the maximum peak-to-peak displacement over the time interval by subtracting the minimum negative displacement from the maximum positive displacement.

For most of the data collection events, SIA personnel provided plots showing the acceleration versus frequency FFT response for each accelerometer, plus calculated peak-to-peak displacement results.

Results of Spring 2004 Vibration Monitoring

Table 6-4 summarizes the calculated displacements, and Figure 6-1 summarizes the key acceleration data. Structural Integrity Calculation HC-06-301, "Hope Creek Recirculation System Vibration Data Reduction," Revision 0 (VTD 326747, Reference 9) summarizes the data collected and provides a more detailed description of the data processing routine.

Review of the data collected revealed the following:

- Early in the testing, the Channel 10 accelerometer failed. This accelerometer had been installed in the Loop B RHR piping in the horizontal direction perpendicular to the pipe axis. Consequently, no acceleration data was obtained for this point. Only data from the remaining 12 accelerometers is discussed herein.

- In general, the acceleration responses were observed at multiples of the pump running speed frequency, with the largest acceleration response occurring at the pump vane passing frequency (five times the pump running speed).

- During the first power ascension (April 12-25 time frame), calculated displacements were relatively small until the plant exceeded 60 percent core thermal power. Up until that time, acceleration data showed significant responses only at multiples of the pump running speed, with a larger response (generally) at the vane passing frequency. However, as the plant rose to 80 percent core thermal power, a significant amount of signal noise appeared in the acceleration data. This signal noise accompanied a step change increase in the displacements calculated by double integration of the acceleration data. This change occurred as the plant ramped up in power from 2054 MWth to 2682 MWth on April 24-25, 2004. The signal noise occurred at all frequencies between 2 Hz and 160 Hz, with a broad peak at 23 Hz and another at about 96 Hz. The signal noise did not directly correlate with pump speed or vane passing frequency. The signal noise appeared in data from all 12 functioning accelerometers, with similar amplitude and frequency characteristics. Figure 6-2, which compares the acceleration responses in one of the accelerometers measured on several different occasions, shows the changes in signal noise observed during each occasion. Notification 20187766 was written to address the step change in signal noise with power level.

  PSEG Nuclear, GE and MPR each reviewed the calculated displacements and each suggested that the displacements calculated for the periods of high signal noise are higher than the actual displacements. This observation was discussed with the Structural Integrity analysts, who also agreed that the calculated displacements likely overstated the actual displacements. The problem stemmed from the presence of signal noise at these higher power levels; this signal noise is not coherent (meaning it does not act in phase to cause piping displacements), but its presence at low frequency has the effect of increasing the displacements calculated by double integration of the acceleration data.

It should be noted that data collected during the small bore testing performed in 1991 exhibited a similar broad band noise centered about 23 Hz, as shown in Attachment B.

- As a result of this noise, plant personnel reduced plant power level and held it at 75 percent of full power for several days. The plant was then brought slowly back up to full power while vibration measurements were recorded at small increments in power. During this second power ascension, the signal noise was absent from the recorded acceleration data, and the calculated displacements were much smaller than during the first power ascension when the signal noise was present. Figure 6-2 includes a sample acceleration plot taken during the second power ascension which shows that the signal noise was not present during this time.

- PSEG Nuclear contracted with a vibration signal analysis expert who performed troubleshooting of the signal noise issue. The expert's report (VibrAlign Report 040555BP, "Evaluation and Vibration Testing of Recirc and RHR Piping Instrumentation," 12-14 May, 2004, VTD 326560, Reference 10) concluded that low level signal noise (not actual vibration) was being amplified as a result of the integration process. Troubleshooting of the installed transducer and data acquisition system showed the signal noise to be electrically induced due to a system ground loop problem, which manifested itself as a peak response at 60 Hz in the raw acceleration data. When this problem was corrected by changing the power supply source, the signal noise diminished and displacements calculated for several recording periods following this correction were smaller than those calculated when the signal noise was present.[1]

- Excluding the data collected when the signal noise level was high, all calculated displacements are less than 0.010 inches and are well within the acceptance criteria.

- There were two instances where data collected with high signal noise present exceeded the displacement acceptance criteria, as shown in Table 6-4. The first case was in Channel 7 data collected at 3.7% of full power, which had a calculated displacement of 32.33 mils and an acceptance criterion of 28 mils. In this case, the cause of the high signal noise was determined to be equipment malfunction. When corrected, the noise disappeared and the calculated displacement dropped to well below the acceptance criterion. The second case was Channel 8 at 91% of full power, which had a calculated displacement of 22.79 mils versus an allowable of 22 mils. As specified by GE in Reference 8, when displacement acceptance criteria are exceeded, an alternative acceptance criteria based on calculated pipe velocity can be used. SIA calculated a velocity of 0.83 inches per second for this case, which was less than the GE alternate acceptance criterion of 1.06 inches per second. Thus, all vibration measurements made in Spring 2004 – even those calculated at times when high signal noise was present – were acceptable.

[1] As shown in Attachment B, the data collected in 1991 also had a strong signal response at 60 Hz, along with the noise at 23 Hz. This may indicate that the same electrical ground problem existed in 1991. Since the 1991 data measured displacements directly (rather than calculating them from double integration of acceleration data as was done in Spring 2004), the noise would not have affected the 1991 measurements significantly.

As stated above, the peak acceleration responses recorded were generally at the pump vane passing frequency, with smaller peaks at the pump running speed (and in some cases at multiples of these frequencies). The peak accelerations varied as a function of pump vane passing frequency, as shown in Figure 6-2. This figure shows the following:

- Accelerations observed at vane passing frequencies below 90 Hz (equivalent to pump running speed of 1080 rpm) are relatively small.

- The acceleration responses have peaks at vane passing frequencies centered around 90 Hz, 105-110 Hz (equivalent to pump running speed of 1080 and 1260-1320 rpm, respectively), and at about 125 Hz (pump running speed of 1500 rpm). Similar behavior was observed in all 12 working accelerometers. Since these accelerometers are in varying locations and orientations throughout the piping system, it is unlikely that these peak responses occurring at the same frequencies can all be attributed to structural resonances. More typically, this behavior is indicative of the presence of acoustic natural frequencies in the piping, which if present can amplify the pressure pulsations, and thereby cause increased vibration, when the pressure pulsation driving force frequency matches the system acoustic natural frequency. Attachment C addresses the possibility that acoustic resonances exist in the system which could cause this result.

- There is also evidence that pump pulsations are exciting discrete structural resonances in several places monitored. For example, as shown in Figure 6-2, the B recirc piping location exhibits a peak response in the vertical and in-line piping directions at about 97 Hz. This may result from a structural resonance of this piping system which has a mode shape with vertical and in-line displacements at this location.

  Note: If a system acoustic resonance frequency coincides with the piping structural resonance frequency, and the system is excited by pressure pulsations at that frequency, the vibratory response of the system can be significantly amplified. This has caused high vibration in other nuclear plants. (Determining whether this is occurring at Hope Creek would require detailed structural evaluation and acoustic modeling of the system and is not in the scope of this common cause analysis.)

- The accelerations generally increase at vane passing frequencies starting about 120 Hz and continue to increase up until the highest vane passing frequency monitored (125 Hz). Whether this is a peak or whether the accelerations continue to increase at higher vane passing frequencies cannot be determined from the data collected to date, since no data has been collected with these accelerometers at pump speeds above 1508 rpm for the A pump or 1500 rpm for the B pump.

Comparison to Previously Recorded Vibration Displacements
Table 6-5 compares the vibration displacements measured throughout the plant life. In brief, the recirculation piping pump suction elbow displacements measured in 2004 are comparable to those recorded during the original startup testing and during the testing of the small bore lines.

Note that no comparable old data exists for the RHR pipe displacements.

6.1.6 Industry Operating Experience

NRC Information Notice 95-16 (Reference 4) and GE SIL 600 (Reference 5) relate experience at other plants with recirculation system piping vibration. In addition, operating experience from other plants was reviewed in Engineering Evaluation H-1-BB-CEE-1830, Attachment B.5. These reports indicate the following:

- Recirculation piping vibration is not unusual in BWRs. Many plants have taken steps to minimize the potential for vibration during operation.

- Plants with MG set recirculation pumps have encountered difficulties with significant recirculation piping vibration at certain pump operating speeds. This is particularly true at very high pump speeds. Note that Hope Creek has encountered the same difficulty.

- At Susquehanna, at elevated recirculation pump speeds with the RHR return line check valve (i.e., comparable to F050A) not fully seated, the pressure pulsations from the recirculation pumps excited acoustic and mechanical resonances in the RHR piping that caused very high vibration levels.

- Pressure boundary failures occurred in small bore lines attached to recirculation piping at Dresden Unit 3 (2002) and WNP-2 (1998). These failures were attributed to vibration degradation.

6.1.7 Summary

Excluding the effect of signal noise in the data collected, the following conclusions are drawn regarding the piping vibration based on the Spring 2004 testing:

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

- Vibration levels observed during the Spring 2004 testing were found to be well below the maximum allowed vibration levels during the testing. Further, the vibration observed in

Spring 2004 is comparable in magnitude to the vibration measured in during startup testing in 1986 and during special testing performed in 1991.

- Vibration accelerations recorded at varying pump speeds showed a sharply increasing trend as the pump speeds approached the maximum recirculation pump speed monitored in this testing (1508 rpm for the A pump, and 1500 rpm for the B pump). The accelerations at higher pump speeds have not been analyzed to date. It is noted that plant procedures allow pump operation at higher speeds than those monitored in this testing.

Also, based on the pattern of acceleration responses seen as a function of pressure pulsation frequency, it is likely that the recirculation/RHR system has one or more acoustic resonances in the frequency range of the pump-induced pressure pulsations. If present, acoustic resonances can amplify the vibrations caused by these pressure pulsations.

6.1.8 Recommendations

- The data collected in Spring 2004 shows that the vibrations are occurring at expected frequencies and at amplitudes that are comparable to previously measured displacements; and that the displacement amplitudes are low relative to the acceptance criteria. However, the data collected showed that the accelerations were trending up as the vane passing frequency increased to 125 Hz, at pump speeds of 1508 rpm for the A pump and 1500 rpm for the B pump. Plant procedures permit operation of the pumps at speeds as high as 1510 rpm, and the plant may operate at higher speeds during special evolutions such as setting the motor generator stop settings. Further, it is possible that operation at higher pump speeds may some day be needed as conditions change or as part of the planned power uprate. If operating the pumps at higher speeds becomes desirable, it is recommended that a set of vibration measurements be recorded when the pumps operate at speeds above 1500 rpm.

- Review of the acceleration data shows that there may be system acoustical natural frequencies which act to amplify the magnitude of pressure pulsations and the resulting vibration accelerations at certain pump speeds. Acoustic modeling of the system is warranted to understand whether planned changes to operating conditions (such as recirculation system temperature and pressure) resulting from the power uprate may result in unfavorable changes to the system acoustical resonances which could result in increased vibration.

Table 6-1

Vibration Displacements Reported for Recirculation Piping During Original Plant Startup (1986)

Parameter / Location		Acceptance Criteria (Level 2/1) (inches peak-to-peak)	Displacements Reported During Startup Testing (inches peak-to-peak) at Varying Power Levels				
			Date: 7/16/86	Date: 10/26/86	Date: 11/11/86	Date: 11/17/86	Date: 12/6/86
Core Flow		--	31%	76.45%	98%	44.96%	43.5%
Power Level		--	N/A	54.62%	98.4%	0.0%	0.0%
RHR Loop A Flow		--	0	0	0	9804 gpm	0
RHR Loop B Flow		--	0	0	0	0	9918 gpm
A Loop Suction Pipe	RA-SX	0.056 / 0.110	0.002	0.007	0.005	0.002	0.010
	RA-SY	0.020 / 0.040	0.002	0.002	0.002	0.002	0.005
	RA-SZ	0.040 / 0.080	0.000	0.010	0.012	0.010	0.007
A Loop at Pump Suction	RA-PX	0.024 / 0.050	0.002	0.010	0.007	0.007	0.012
	RA-PY	0.020 / 0.040	0.000	0.007	0.007	0.012	0.012
	RA-PZ	0.030 / 0.060	0.002	0.007	0.007	0.007	0.010
A Loop Discharge Elbow	RA-DX	0.030 / 0.060	0.002	0.007	0.010	0.007	0.012
	RA-DY	0.030 / 0.060	0.002	0.007	0.007	0.010	0.015
	RA-DZ	0.100 / 0.200	0.000	0.007	0.007	0.010	0.007
A Loop at RHR Return	RA-HX	0.056 / 0.110	0.002	0.007	0.005	0.012	0.010
	RA-HY	0.024 / 0.050	0.002	0.007	0.012	0.007	0.010
	RA-HZ	0.090 / 0.180	0.002	0.007	0.012	0.007	0.010
B Loop Suction Pipe	RB-SX	0.056 / 0.110	0.002	0.007	0.007	0.007	0.015
	RB-SY	0.020 / 0.040	0.002	0.007	0.007	0.010	0.012
	RB-SZ	0.040 / 0.080	0.000	0.007	0.007	0.012	0.010
B Loop at Pump Suction	RB-PX	0.024 / 0.050	0.002	0.012	0.007	0.010	0.012
	RB-PY	0.020 / 0.040	0.000	0.010	0.010	0.012	0.017
	RB-PZ	0.030 / 0.060	0.002	0.010	0.007	0.007	0.010
B Loop Discharge Elbow	RB-DX	0.030 / 0.060	0.002	0.007	0.010	0.012	0.012
	RB-DY	0.030 / 0.060	0.002	0.002	0.002	0.002	0.010
	RB-DZ	0.100 / 0.200	0.000	0.002	0.002	0.000	0.005
B Loop at RHR Return	RB-HX	0.056 / 0.110	0.002	0.000	0.002	0.002	0.002
	RB-HY	0.024 / 0.050	0.002	0.002	0.002	0.000	0.007
	RB-HZ	0.090 / 0.180	0.000	0.002	0.000	0.002	0.005

Reference: Procedure Number TE-SU.BB-332(Q), "Recirculation System Piping Steady State Vibration Surveillance Test," Revision 2: test records from data collected in 1986 (Reference 11). Per GE document 22A5405AW (VTD PNO-A12-3331-0002 (1) -03), Reference 12, the Y values are vertical displacements and the X and Z are perpendicular horizontal displacements.

Table 6-2

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.

Run-up data taken on 9-23-91 at pump speed 1297 RPM (B Loop, BB-328) Pump Running Speed = 21.6 Hz Pump Vane Passing Frequency = 108 Hz					
Vertical		Horizontal		Horizontal	
Frequency	Displacement	Frequency	Displacement	Frequency	Displacement
21.6	1.80	21.6	1.00	21.6	0.88
43.0	0.38	24.7	0.37	40.0	0.50
60.0	0.19	28.5	0.42	60.0	0.75
86.0	0.25	40.0	0.72	86.0	0.50
108.0	1.60	60.0	0.95	108.0	3.80
180.0	0.18	86.0	0.43	180.0	0.38
		108.0	0.79		
		180.0	0.43		
	Sum: 4.40		Sum: 5.11		Sum: 6.81

100% Power data taken on 8-1-91 at pump speed 1430 RPM (B Loop, BB-328) Pump Running Speed = 23.8 Hz Pump Vane Passing Frequency = 119 Hz					
Vertical		Horizontal		Horizontal	
Frequency	Displacement	Frequency	Displacement	Frequency	Displacement
14.60	0.32	14.50	0.20	15.70	0.30
20.83	0.90	20.83	0.55	20.83	0.75
23.98	1.40	23.98	0.50	48.20	0.20
60.0	0.25	60.0	1.00	60.0	0.65
119.92	0.30	119.92	0.70	119.92	0.40
	Sum: 3.17		Sum: 2.95		Sum: 2.30

2nd run-up data taken on 9-23-91 at pump speed 1318 RPM (B Loop, BB-328) Pump Running Speed = 21.97 Hz Pump Vane Passing Frequency = 109.8 Hz					
Vertical		Horizontal		Horizontal	
Frequency	Displacement	Frequency	Displacement	Frequency	Displacement
13.7	0.20	20.0	0.975	20.0	0.70
21.97	1.70	24.0	0.80	22.0	0.65
44.0	0.25	40.0	0.725	40.0	0.50
62.0	0.13	60.0	0.90	60.0	0.75
87.5	0.13	84.0	0.45	110.0	1.35
109.85	2.40	109.85	1.30	180.0	0.40
		180.0	0.37		
		220.0	1.30		
	Sum: 4.81		Sum: 6.82		Sum: 4.35

Run-up data taken on 9-23-91 at pump speed 1328 RPM (A Loop, BB-321) Pump Running Speed = 22.1 Hz Pump Vane Passing Frequency = 110 Hz			
Vertical		Horizontal	
Frequency	Displacement	Frequency	Displacement
18.0	0.35	20.0	1.72
22.0	1.45	22.0	1.81
60.0	0.25	29.0	0.54
91.0	0.15	32.0	0.55
98.0	0.20	40.0	1.15
110.0	0.15	60.0	1.66
		120.0	0.31
		140.0	0.44
	Sum: 2.55		Sum: 8.18

100% Power data taken 9-23-91 at pump speed 1496 RPM (A Loop, BB-321) Pump Running Speed = 24.9 Hz Pump Vane Passing Frequency = 125 Hz			
Vertical		Horizontal	
Frequency	Displacement	Frequency	Displacement
22.0	1.20	19.0	0.94
28.0	0.20	22.0	1.95
60.0	0.20	26.0	0.875
120.0	0.15	28.0	0.875
		40.0	0.50
		60.0	1.88
		89.0	0.375
		125.0	0.375
	Sum: 1.75		Sum: 7.77

Table 6-3. Summary of Displacements Measured During 1991 Small Bore Line Testing (from Reference 2)

Units:
--Frequencies in Hz.
--Displacements in mils peak-to-peak.

Table 6-4

Displacements Calculated at Accelerometer Locations during Spring 2004 Power Ascensions

Hope Creek

Calculated Peak-to-Peak Displacements (mils) at Each Power Level (2004 Date / % Core Thermal Power / MWth)

First Power Ascension (April 10 - April 25, 2004)

Channel Number	Accelerometer Location	Accel Axis	Pipe Size	Acceptance Criteria	4/7	4/10	4/12	4/13	4/17	4/18	4/18	4/19	4/22	4/24	4/23	4/24	4/24	4/24	4/25	4/25	4/25
					0	3.7%	7.8%	21.0%	34.9%	37.3%	44.2%	44.4%	61.5%	80.3%	80.3%	86.9%	89.5%	91.6%	91.0%	81.7%	74.9%
					0	124	260	702	1166.6	1245.6	1477	1481	2054	2682	2682	2902	2987	3060	3040	2727	2502
1	Loop A	Vert	12"	64	1.89	1.89	1.76	1.62	1.63	1.72	2.06	1.73	3.81	15.43	15.79	22.32	22.60	22.98	24.47	18.38	14.16
2	RHR Return	Inline	12"	32	2.14	2.10	2.22	1.89	1.90	1.91	2.19	1.93	2.94	12.39	13.53	19.07	18.95	19.08	20.27	16.43	11.98
3	@F050A	Perpend	12"	176	2.61	2.77	2.71	2.45	2.32	2.40	2.48	2.43	3.26	13.45	14.23	19.18	20.35	20.55	22.04	16.76	12.80
4	Loop A	Inline	28"	60	0.91	0.74	0.81	0.67	0.72	0.77	0.83	0.87	3.88	14.65	15.28	20.08	21.29	22.09	23.20	18.14	13.34
5	Recirc Pump	Perpend	28"	76	2.92	3.00	2.74	2.48	2.54	2.42	2.94	3.67	4.46	15.08	15.68	21.37	22.55	23.07	24.39	18.29	14.34
6	Suction Line	Vert	28"	30	1.60	1.44	1.31	1.58	1.25	1.45	19.68	1.73	3.73	14.80	21.02	21.45	21.10	22.99	24.02	18.18	13.74
7	Recirc Line-JP	Vert	12"	28	1.97	32.33	2.61	1.47	1.70	1.95	2.04	2.12	3.35	15.56	15.74	21.11	20.58	22.08	23.52	18.58	13.31
8	Loop B	Vert	12"	22	3.53	3.56	3.54	2.90	2.87	2.98	3.08	3.11	3.36	13.64	14.94	19.84	20.70	21.38	22.79	16.78	12.91
9	RHR Return	Inline	12"	280	3.09	3.12	3.00	2.80	2.60	2.84	2.64	4.69	6.40	13.78	14.71	17.35	18.43	18.58	19.85	15.03	11.15
10	@F060B	Perpend	12"	42	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
11	Loop B	Vert	28"	28	0.73	0.67	0.70	0.76	0.79	0.90	0.86	1.01	3.85	15.67	16.56	22.21	22.56	23.32	25.90	18.72	14.38
12	Recirc Pump	Inline	28"	60	1.66	1.66	1.66	1.65	1.61	1.91	1.60	1.78	3.45	13.13	14.31	19.87	20.16	20.41	22.63	16.57	12.49
13	Suction Line	Perpend	28"	58	1.61	1.35	1.91	1.65	1.15	1.20	2.18	1.53	3.50	14.56	14.95	20.04	21.59	21.47	23.08	16.94	13.52
				Maximum:	3.53	32.33	3.54	2.90	2.87	2.98	19.66	4.69	6.40	15.67	21.02	22.32	22.60	23.32	25.90	18.72	14.38
				Average:	2.05	4.55	2.08	1.83	1.76	1.87	3.55	2.22	3.83	14.34	15.56	20.31	20.90	21.50	23.01	17.40	13.18

← Highlighted displacements are from times when there was significant noise in the acceleration data

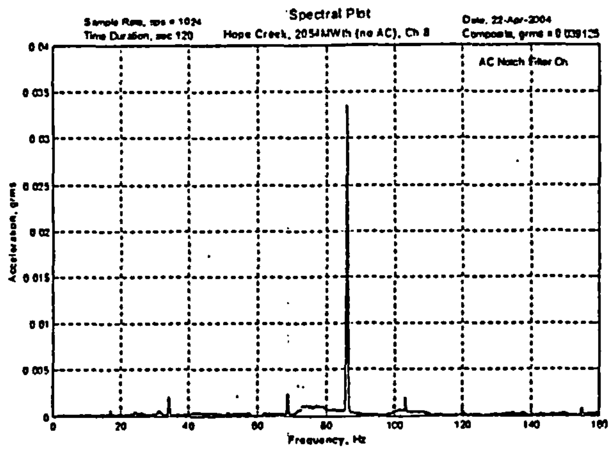
Second Power Ascension (April 29 - May 3, 2004)

Channel Number	Accelerometer Location	Accel Axis	Pipe Size	Acceptance Criteria	4/29	4/29	4/29	4/30	4/30	4/30	4/30	4/30	5/1	5/1	5/1	5/1	5/1	5/1	5/1	5/2	5/2	5/3	Max Displacement With Noise	Max Displacement Excluding Noise
					74.0%	79.0%	80.4%	83.6%	89.9%	92.9%	92.7%	92.6%	92.5%	93.2%	94.4%	93.7%	93.8%	94.1%	94.1%	96.5%	100%	99.8%		
					2472	2637	2683	2790	3001	3103	3094	3092	3089	3113	3151	3129	3133	3143	3143	3222	3335	3331		
1	Loop A	Vert	12"	64	1.95	1.71	1.74	2.37	2.71	2.22	2.51	1.98	1.83	2.06	2.31	2.28	4.19	5.60	5.59	2.03	2.17	3.03	24.47	5.60
2	RHR Return	Inline	12"	32	2.22	2.07	3.31	3.96	4.28	2.36	2.69	2.09	2.50	3.06	2.54	2.25	3.19	3.58	4.42	3.05	2.22	2.93	20.27	4.42
3	@F050A	Perpend	12"	176	2.37	2.56	2.84	2.74	3.36	3.05	2.71	2.95	3.04	2.65	2.76	2.58	3.15	5.57	7.71	2.71	2.59	3.31	22.04	7.71
4	Loop A	Inline	28"	60	1.09	1.05	1.50	1.35	1.17	1.56	1.35	1.44	1.42	1.58	1.50	1.39	1.61	1.55	1.57	1.38	1.48	1.38	23.20	3.88
5	Recirc Pump	Perpend	28"	76	2.98	3.90	3.15	2.84	2.88	3.48	2.81	2.85	3.11	2.75	2.81	2.91	2.78	2.99	3.07	2.79	2.98	3.02	24.39	4.45
6	Suction Line	Vert	28"	30	1.41	1.80	1.73	2.16	1.63	1.57	1.91	3.65	1.64	1.81	5.25	2.33	3.08	2.89	6.25	2.04	2.22	2.52	24.02	6.25
7	Recirc Line-JP	Vert	12"	28	2.24	2.27	3.58	3.96	3.03	2.45	2.42	2.13	2.39	2.38	2.44	2.35	2.48	2.85	3.12	2.71	2.56	2.64	32.33	3.96
8	Loop B	Vert	12"	22	3.24	3.01	3.30	3.00	3.16	3.62	3.23	3.26	3.27	3.27	2.92	3.04	3.29	3.49	3.36	3.11	3.11	3.00	22.79	3.62
9	RHR Return	Inline	12"	280	3.25	6.92	3.85	2.85	3.17	3.56	3.74	2.85	3.01	3.17	3.27	3.70	4.24	4.00	3.64	3.50	3.78	3.31	19.85	6.92
10	@F060B	Perpend	12"	42	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data		
11	Loop B	Vert	28"	28	1.10	1.07	1.40	1.46	1.47	1.90	2.06	1.71	1.75	2.00	2.18	2.38	2.67	2.92	2.72	1.98	2.40	2.51	25.90	3.65
12	Recirc Pump	Inline	28"	60	1.25	1.69	2.08	2.03	2.09	2.32	1.94	2.16	2.12	2.12	2.49	2.80	2.29	2.58	2.25	2.08	2.82	2.43	22.63	3.45
13	Suction Line	Perpend	28"	58	1.53	1.46	1.86	1.56	2.05	3.14	2.35	2.67	2.54	2.57	2.67	3.18	2.44	2.97	2.60	2.83	3.11	2.42	23.06	3.50
				Maximum:	3.25	6.92	3.85	3.96	4.28	3.62	3.74	3.65	3.27	3.27	5.25	3.70	4.24	5.60	7.71	3.50	3.78	3.31		
				Average:	2.05	2.46	2.53	2.52	2.59	2.60	2.45	2.48	2.39	2.45	2.76	2.60	2.95	3.42	3.86	2.52	2.62	2.71		

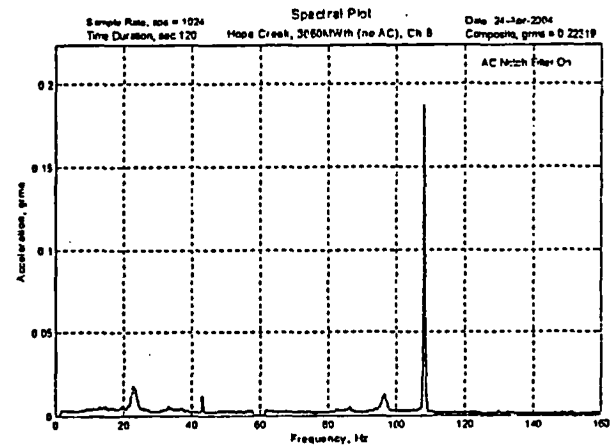
Table 6-5

Comparison of Recirculation Pipe Vibration Data Collected Throughout Hope Creek History

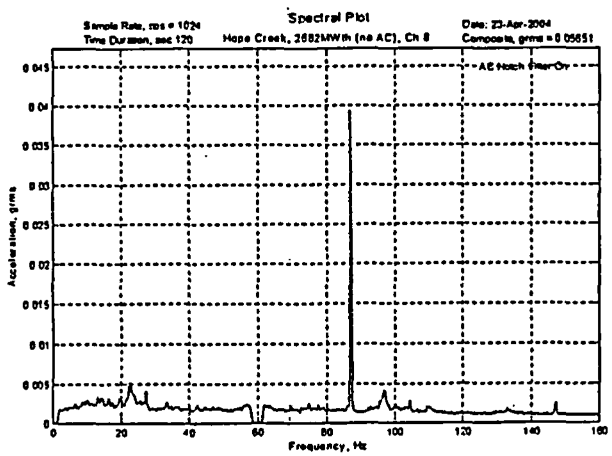
Parameter	Original Startup Data	Data Collected during Small Bore Line Testing	Data Collected during Common Cause analysis
Year	1986	1991	2004
Max Displacements at Loop A Recirculation Pump Suction Elbow	0.007" Vertical; 0.007" and 0.010" Horizontal[1]	0.0026" Vertical; 0.008" Horizontal[2]	0.006" Vertical; 0.004" and 0.004" Horizontal[3]
Max Displacements at Loop B Recirculation Pump Suction Elbow	0.010" Vertical; 0.012" and 0.010" Horizontal[1]	0.005" Vertical; 0.005" and 0.007" Horizontal[2]	0.004" Vertical; 0.0035" and 0.0035" Horizontal[3]
Reference	Table 6-1	Table 6-3	Table 6-4
Notes	(1) Maximum results for tests at power, excluding vibrations measured when RHR system was flowing.	(2) Only one horizontal axis was monitored at this point in 1991	(3) Max values are taken from Table 6-4 excluding data with high noise content



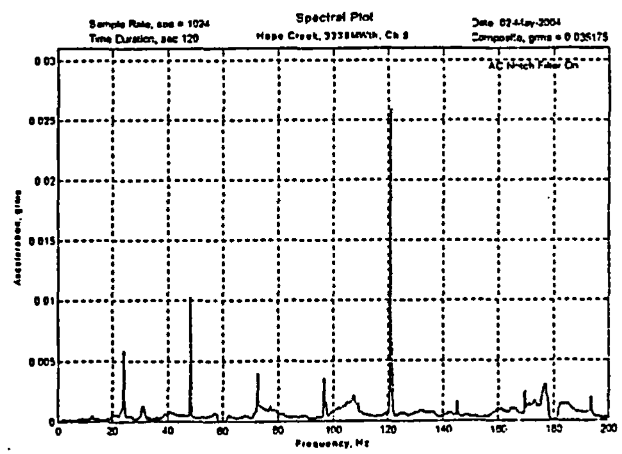
Data taken at 2054 MWth on April 22, 2004
Little or No Noise Present; Calculated Displacement = 3.4 mils peak-to-peak



Data taken at 3060 MWth on April 24, 2004
Noise Present; Calculated Displacement = 21.4 mils



Data taken at 2682 MWth on April 23, 2004
Noise Present; Calculated Displacement = 13.6 mils



Data taken at 3338 MWth on May 2, 2004
Little or No Noise Present; Calculated Displacement = 3.1 mils

Figure 6-1. Noise in Acceleration Data and its Effect on Calculated Displacements

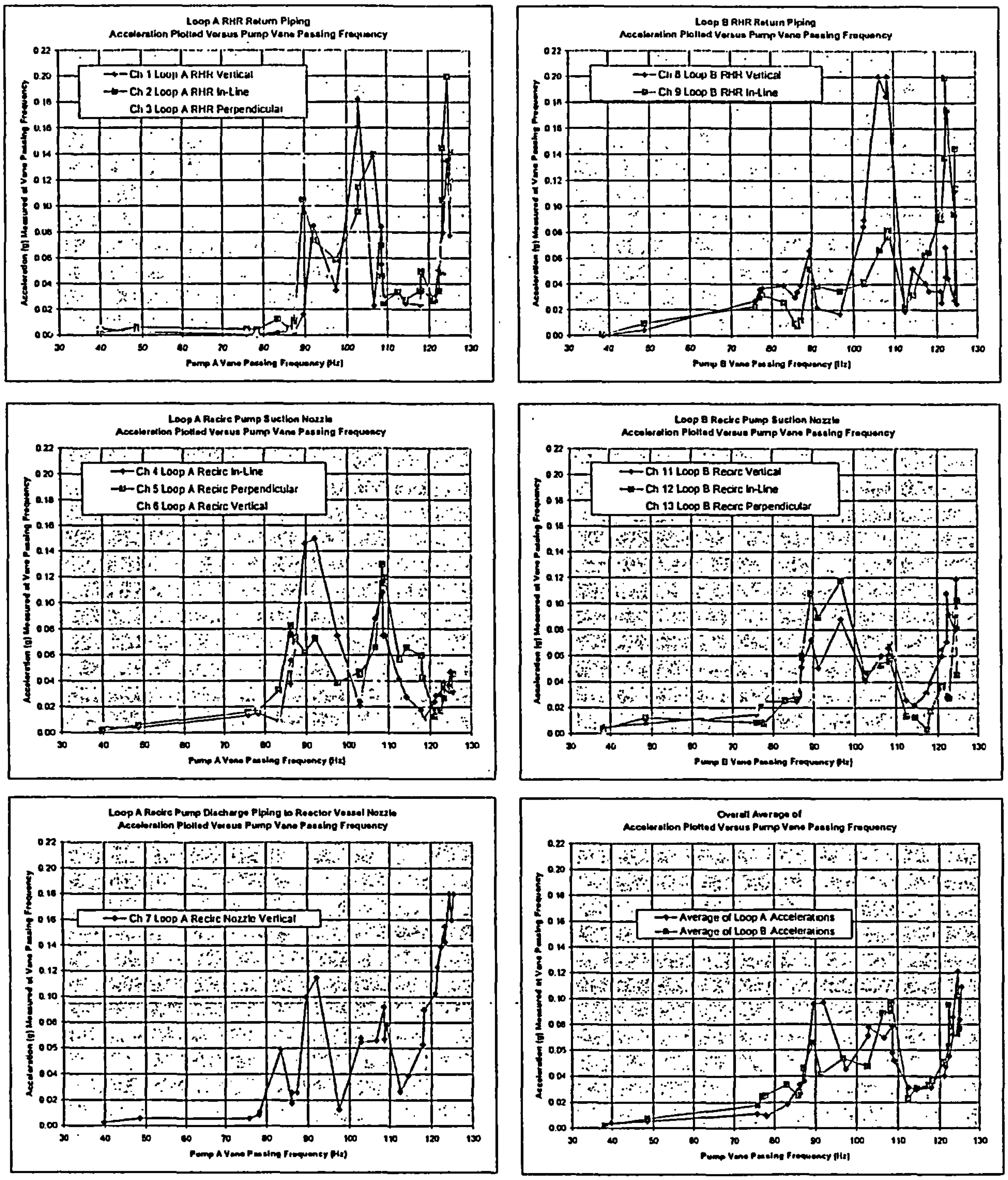


Figure 6-2
Accelerations Recorded in Spring 2004 Plotted Versus Pump Vane Passing Frequency

6.2 F050A Actuator Damage

6.2.1 Description of Damage

During the March 2004 outage, inspection personnel found that the air piston cylinder for the actuator on testable check valve 1BC-HV-F050A was detached from the actuator assembly. The cylinder is normally threaded onto a casting which is in turn bolted onto the side of the check valve body. The threaded connection is also secured with a cap screw that acts as a set screw to prevent the cylinder from unthreading and rotating off the casting.

Photographs provided in Attachment A show the as-found position of the cylinder when found in the drywell, and close-up views of the affected components after they were removed from the drywell for study. The following observations were made during review of the damage:

- A lockwasher was found installed between the cap screw and the cylinder. The lockwasher does not appear on the design drawing for the valve. Per discussions with the vendor, the lockwasher is not part of the design. Plant inspections found that all similar valves installed in the field and in the plant spare parts inventory had lockwashers installed in this location.

- The cap screw did not protrude beyond the ID of the actuator cylinder. With the lockwasher in place, the cap screw should have extended 3/16" inside the actuator.

- The cap screw appears to have gouged out a groove which extends from the indentation in the casting (at the nominal contact point for the cap screw) to nearly the bottom edge of the casting thread length. The groove is nearly straight and does not follow the thread path. The gouge is deepest at the point where the cap screw nominally contacts the casting, and becomes shallower with increasing distance from this point. This provides evidence that the cylinder was pulled off the casting threads, rather than rotated off.

- There was little or no evidence of damage to the inner and outer surfaces of the cylinder.

- The male threads on the casting were flattened over a small portion of the circumference, and for the last 1-2 threads at the end of the casting; but for the greater part of the circumference, no obvious flattening or degradation was noted. The female threads on the cylinder did not appear to be damaged.

- As found dimensions taken of the affected components are as follows (see H-1-BB-CEE-1830, Attachment B-9):

Cylinder OD	= 5.500 in, 5.5006 in (90 degrees apart)
Cylinder thread ID	= 5.086 in, 5.076 in (90 degrees apart)
Cylinder thread length	= 1-3/16 in

End cap thread OD (casting)	= 5.079 in, 5.076 in (90 degrees apart)
End cap thread length	= 1 in
Cap screw length (end of fracture)	= 5/16 in
Original cap screw length	= 1/2 in (vendor provided)
Lockwasher thickness	= 1/16 in
Lockwasher OD	= 1/2 in
Lockwasher ID	= 1/4 in
Air cylinder piston OD	= 4.995 in, 4.995 in (90 degrees apart)
Cylinder wall thickness (threaded area)	= (5.500 – 5.086) / 2 = 0.207 in
(90 degrees apart)	= (5.506 – 5.076) / 2 = 0.215 in

The damaged cylinder and casting were removed from the drywell and replaced with new equipment prior to restart.

6.2.2 Causal Factor Table

See Attachment F for the causal factor table for the observed degradation. Possible causes considered include insufficient thread engagement due to an original machining mistake; application of high cycle, low level vibration leading to gradual wear and failure; and application of high amplitude loads that "shook" the cylinder off the casting. Investigations performed in the evaluation of these possible causes are summarized below.

6.2.3 Analysis of Threads

The dimensions reported above indicate that there was little thread engagement on the as-found pieces. Per the valve vendor, the cylinder threading is 5.13 x 12 UN 2B and the cap threading is 5-1/8 x12 UN 2A (Reference: H-1-BB-CEE-1830, Attachment B.8). These dimensions are also significantly different from the as-designed thread sizes for a 5-1/8"-12 UN-2A/2B threaded connection, as shown in the comparison below:

Dimension	ASME B1.1 Value	As-Found	Comparison
External Thread Major Diameter	5.1230 in Max 5.1116 in Min	5.079 in, 5.076 in (90 degrees apart)	External threads on casting smaller than min expected by >0.030 in
Internal Thread Minor Diameter	5.053 in Max 5.035 in Min	5.086 in, 5.076 in (90 degrees apart)	Internal threads on cylinder larger than max expected by >0.020 in

The comparison shows that both as-found pieces are outside the expected range; that is, the cylinder ID is larger and the casting thread OD is smaller than the expected range. This means that the threaded joint had less engagement than the as-designed configuration would have had.

The cause for this out-of-tolerance condition is not known. One possibility is that the pieces were manufactured incorrectly. Although plausible, for this to be true, both pieces would have to have been incorrectly machined, in the worst possible configuration.

The second possibility is that the pieces were correctly machined and then degraded under the actions of loads applied in service. These loads include deadweight, reaction to pressure force applied to the cylinder when the actuator is energized, and oscillating loads applied by pipe vibration.

Attachment E.1 calculates the force required to strip the threads of a properly dimensioned threaded connection of this type to be on the order of 100,000 pounds. The cylinder does not experience anything close to that during normal operation; for instance, under the applied air pressure of 70 psig used to actuate the piston in the cylinder, the total force on the nominal 5" ID of the cylinder is about 1400 pounds force. Based on this result, it is concluded that the actuator deadweight (estimated at less than 30 pounds) and the normal actuation pressure were not sufficient to cause the threaded connection to fail.

Oscillating loads applied to the threaded connection could cause slight movement of the male threads relative to the female threads. If the movement were enough to cause the thread surfaces to rub against each other, the threads would eventually begin to wear at the contact points. Based on several of the photographs in Attachment A (see for example Photograph A.1-12), some thread wear had occurred at points along the casting circumference. Relative motion of the two parts would also result on wear on the tip of the cap screw. With time, continuing wear of the threads on the cylinder and casting would open up clearances between the two parts, which in turn would permit more relative motion and lead to accelerated wear. Once the clearances between the two parts opened up enough to permit the cylinder to begin moving down the threads, the cap screw would become loaded in shear. With time, the continued vibration would wear down the cap screw tip, permitting even more relative motion.

The fact that there is little overlap between the male and female parts of this threaded connection supports this scenario. Note that the thread wear is most pronounced on the casting, which is likely the softer of the two components.

Eventually, the cap screw wore to the point where it could no longer retain the cylinder in place, and the cylinder fell off due to deadweight and vibratory loads. The gradual wear of the tip of the cap screw is evidenced by the fact that the depth of the gouge in the casting becomes shallower with increasing distance from the nominal contact point. In addition, the remaining end of the cap screw appears polished, as shown in Photograph A.1-20. Further, the gouge surface appears fretted or highly polished (Photograph A.1-11), which would be expected if the damage were caused by a high frequency, oscillating load.

6.2.4 Modal Analysis

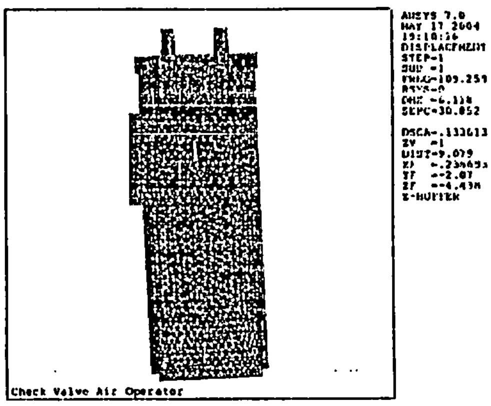
The RHR piping is subject to pressure fluctuations resulting from the recirculation pump rotation. As discussed earlier, these include pressure fluctuations at the pump running speed (1X) and at the pump vane passing frequency (which occurs at five times the pump running speed, or 5X). The piping experiences motion due to these fluctuations as discussed in Section 4.1 of this report at frequencies ranging from as low as 7.5-25 Hz to as high as 37.5-125 Hz.

To determine whether the air piston cylinder has a natural frequency in this range, a ring test could be performed of the actuator. In lieu of such a test, a modal analysis was performed of the air piston and casting geometry. This required construction of a computer model of the assembly geometry. To create this model, the configuration of the assembly was determined from Atwood & Morrill Drawing 14053-01-H (PSEG VTD PN1-E11-F041-0388, Reference 13), from the field measurements listed above, and from scaling several dimensions from the photographs shown in Attachment A. Key inputs to this model are listed in Attachment E.4. The model included a fixed boundary condition at the point where the casting is bolted to the check valve body. The computer program ANSYS was used to determine the natural frequencies associated with motion of this assembly.

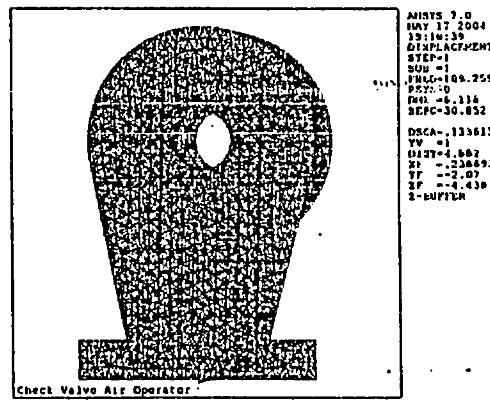
The analysis results show that the air piston/casting assembly has two vibration modes that have natural frequencies in the range of the 5X vane passing frequency:

- Mode 1 occurs at 109 Hz. In this mode, the bottom of the cylinder sways back and forth in a plane parallel to the pipe axis.
- Mode 2 occurs at 125.6 Hz. In this mode, the bottom of the cylinder sways toward and away from the valve body (in a plane that is perpendicular to the pipe centerline).

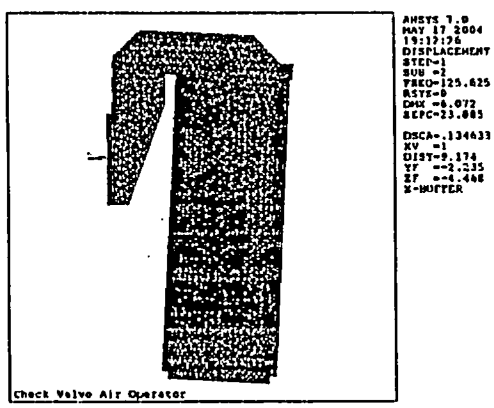
Figure 6-3 shows these mode shapes. Both of these modes would tend to work the cylinder off of the casting. This likely contributed to the loading on the casting threads and probably acted to flatten them on portions of the thread OD.



Mode 1 Displacement Shape
View from Back of Bracket



Mode 1 Displacement Shape
View from Top of Bracket



Mode 2 Displacement Shape

Figure 6-3. F050A Actuator Modal Displacement Shapes

The first mode will be excited by pipe motion along the pipe axis, and the second mode will be excited by horizontal pipe motion in a plane perpendicular to the pipe axis. As shown in Figure 6-2, the Loop A RHR accelerometers located on the large bore RHR pipe near the F050A actuator recorded 5X vane passing frequencies peaking at 0.14 g's (in the perpendicular direction) and 0.20 g's (in the in-line direction). Further, the accelerations seem to be increasing as the pump speed increased near 125 Hz; it is not known at this time whether the accelerations at vane passing frequencies occurring at higher pump speeds than were monitored are actually higher than 0.2 g's.

In a poorly damped system, excitation at the natural frequency can lead to significantly amplified accelerations of the oscillating components. For instance, Regulatory Guide 1.61 (Reference 14) recommends using damping values as follows for seismic design of nuclear power plant structures and components:

- Small diameter piping systems with diameter less than or equal to 12": 1 percent of critical damping
- Bolted steel structures: 4 percent of critical damping

The actuator is bolted to a 12" piping system; so the damping value per this regulatory guide could be either 1 or 4 percent. If these damping values are used, and the system is excited by a forcing function applied exactly at its natural frequency, the acceleration amplification can range from a multiplier of 6.25 (for four percent damping) to as high as 100 (for one percent damping). In the worst case, if the 0.2 g maximum pipe acceleration occurred at a forcing frequency equal to the system natural frequency, the resulting acceleration of the mass would be 20 g's (factor of 100 times 0.2 g's). Application of this acceleration to the cylinder mass of about 20 pounds would result in an oscillating force of about 400 pounds occurring as long as the system operated at this forcing frequency. This force alone is not sufficient to fail the connection; however, acting as an oscillating load, the force could contribute to the degradation.

In brief, the key result of this analysis is that the pump vane passing frequencies ranging from 37.5-125 Hz can excite these two modes of vibration of the actuator. The resulting vibration could have contributed to the degradation seen in this component.

6.2.5 OE Experience

PSEG Nuclear personnel contacted the vendor to determine if this problem had been reported elsewhere. The vendor did not know of any instance where similar damage had been observed.

As reported in Engineering Evaluation H-1-BB-CEE-1830:

- Similar testable check valves of the same design were also inspected

  -- H1BC-BC-HV-F050B
  -- H1BC-BC-HV-F041A/B/C/D
  -- H1BC-BC-HV-F006A/B

  All of the subject valves were inspected verifying that the cylinders and retaining cap screws tight and secure. The presence of a lock washer was noted on all of the subject valve applications.

- No record of similar damage was identified in a search of OE data.

6.2.6 Summary

Based on the above, the following conclusions are reached:

- The fact that there was little overlap seen in the as-found threaded joint indicates that either the components were incorrectly machined originally, or that the threads degraded in service.

- The as-designed threaded connection (that is, the connection before it experienced degradation and with the as-designed thread configuration) was sufficiently strong to withstand the normal applied pressure loads on the actuator and the actuator deadweight under static conditions.

- Vibration data recorded in Spring 2004 show that oscillating accelerations occur at the location of this valve. At certain recirculation pump speeds, accelerations occur (due to vane passing) at frequencies at or near structural modes which would cause the cylinder to sway relative to the casting.

- The acceleration-induced swaying motion of the cylinder caused relative motion of the male and female threads where they contact each other in the threaded joint, leading to the thread wear observed and to increased clearances. As the clearances increased, the magnitude of the resulting relative motion increased, leading to accelerated wear. This continued until the thread clearances opened up to the point where there was little overlap in the threaded joint. As this occurred, the cap screw began to become subjected to the oscillating loads.

- As the thread overlap diminished, the cap screw picked up the retention force. With time and continued vibration of the cylinder, the cap screw tip began to wear away, which allowed the cylinder to begin to slide off the casting. Contact between the casting and cap screw caused the cap screw to wear out a gouge in the casting. Eventually, the wear progressed to the point where the remaining portion of the cap screw either failed or shortened to the point where it could not retain the cylinder.

6.2.7 Recommendations

- The F050A valve will continue to experience accelerations due to pump pressure pulsations. Accordingly, to ensure that the observed degradation does not recur, it is recommended that the valve actuator be modified. Modifications to consider are as follows:
    - Change the actuator natural frequency such that it will not become excited by the expected pump pulsation frequencies. Suggested approaches include stiffening the actuator (by tying it back to the valve body) or changing its length and/or mass.
    - Prevent relative motion between the cylinder and casting. One suggested approach is to weld the two components together.

- At the next refueling outage, disassemble the F050A actuator and check the threads and cap screw for signs of degradation. This step is recommended since the replacement actuator was installed without taking mitigating action, other than ensuring it was properly threaded.

If the degradation seen in Spring 2004 was due to relative motion of the correctly machined threads due to vibration, then some damage may have occurred between the time the correctly machined components were installed in Spring 2004 and the next refueling outage. If no damage has occurred, this supports the theory that the damage was due to the original components being incorrectly machined.

- Inspect the F050A actuator each refueling outage to ensure that the cylinder has not loosened or become detached. Because the valve will continue to be subjected to pressure pulsations, continued inspection is recommended to ensure that the modification has effectively corrected the problem. If future inspections show that the degradation is not recurring, it may be acceptable to stop doing this inspection.

- During the next refueling outage, inspect the other valves in containment that have the same type of actuator, to ensure that the air piston cylinder has not loosened or become detached:

  -- H1BC-BC-HV-F050B
  -- H1BC-BC-HV-F041A/B/C/D
  -- H1BC-BC-HV-F006A/B

Note: The piping accelerations occurring at these locations have not been determined. Although to date there has been no reports of similar degradation at these locations, this inspection is recommended since the valves are likely to have similar structural resonances and therefore eventually be subject to the same type of degradation.

6.3 Detachment of F060B Handwheel

6.3.1 Description of Damage

During the March 2004 outage, inspection personnel found that the handwheel had fallen off of the operator on valve 1BC-HV-F060B. This is a manual block valve located inboard of the testable check valve 1BC-HV-F050B in the "B" loop RHR return line. The 1BC-HV-F060B valve is stroked during surveillance testing or maintenance of valve 1BC-HV-F050B; otherwise, it is normally locked open using lockwire attached to an adjacent structure.

The handwheel was found suspended from its lockwire near the F060B operator where it had previously been attached. The retaining ring that normally holds the handwheel on its hub (also known as a wrench nut adapter) was missing and has not been located.

The handwheel is known as a knocker type handwheel. The handwheel rotates freely around a hub until a stop on the handwheel contacts a similar stop on a hub mounted on the manual operator bevel gear pinion shaft. The handwheel is prevented from sliding off the hub by a retaining ring inside a groove in the hub OD. The hub is mounted on a bevel gear pinion shaft which rotates with the handwheel and turns a gear in the operator to raise or lower the shaft. When not held in place with a lockwire, the handwheel can freely rotate around the hub until the stops on the handwheel contact the stops on the hub. When operating the valve, the handwheel is turned quickly to create an impact of the stops; this impact force helps start the motion of the stem.

Photographs in Attachment A show the handwheel and hub, and their as-found condition. The following degraded conditions were observed:

- The handwheel was cracked. The crack appears to have originated at the toe of the weld connecting one of the stops to the handwheel.
- Wear areas were present on the handwheel and hub in places where the two components could bear against each other. At these locations, the handwheel paint was worn away and the handwheel and hub metal surfaces were worn to the point of being polished.
- Of particular interest was the wear on the hub at the bearing surface where the handwheel nominally contacts the hub. The outer diameter of the hub was worn by as much as 3/16" along an arc extending approximately 120 degrees around the circumference. The wear surface appeared polished.
- The hub also had a wear area part way down its shaft. As shown in an Attachment A photograph, this wear mark occurs at the location where the handwheel would contact the

hub if the handwheel were to become loose from its nominal position and cock up against the hub.

The wear observed is similar to fretting type wear that occurs with high frequency, low amplitude vibration.

Prior to restart following the March 2004 outage, Hope Creek personnel replaced the handwheel and hub and secured the handwheel from motion using lockwire.

6.3.2 History

Table 6-6 summarizes incidents related to handwheels on the F060A and F060B valves obtained during a search of Hope Creek records. The table shows that there were at least four previous instances in which the F060B valve handwheel either fell off or the shaft supporting the handwheel sheared.

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.

6.3.3 Causal Factor Table

See Attachment F for the causal factor table for the observed degradation. Possible causal factors considered include long term wear due to normal pipe vibrations and short term wear due to high vibration loads occurring over a short period of time.

6.3.4 Review of Degradation Observed

The presence of highly polished surfaces indicates that before the handwheel detached from the hub, it had been subjected to a long period of high frequency vibration, causing the surfaces to contact and abrade one another. The loss of section at the nominal contact point between the hub OD and handwheel ID would eventually cause the retaining ring to lose its grip on the hub. Once that happens, the ring would likely fall off the hub and no longer be present to keep the handwheel in place.

With the retaining ring no longer in place, the handwheel would be free to move. It is noted that the F060B valve is oriented such that the pinion shaft points downward at a 45 degree angle; this, coupled with continued vibration, would help to move the handwheel off the hub.

The handwheel ID is slightly greater than the hub OD (which enables the handwheel to fit over the hub during installation). However, there is not a large difference in diameter. Accordingly, once the handwheel becomes free to move off the hub, it can "cock" up against the hub. Photograph A.2-5 shows the handwheel in a possible cocked position. (This photo shows manipulation of these components performed by engineers during the common cause analysis; it does not depict an as-found condition.) It is noted that when the handwheel was placed in this position, the ID of the handwheel contacted the hub at a location where the hub showed wear. From this observation it is assumed that the handwheel was caught temporarily in this cocked position for a length of time until the hub wore sufficiently to permit the handwheel to move again. At that time, the handwheel likely fell off of the hub.

Vibration data collected in Spring 2004 shows that piping near the F060B valve location experiences accelerations as high as 0.2 g's in the vertical and in-line directions. (The accelerometer installed to measure perpendicular accelerations at this location failed in service.) It is noted that the valve yoke assembly is perpendicular to the pipe axis, and the handwheel pinion shaft is perpendicular to the valve yoke axis; therefore, movement of the large bore piping in any direction (vertical, horizontal along the pipe axis, or horizontal perpendicular to the pipe axis) will act to vibrate the handwheel at the end of the pinion shaft.

6.3.5 Modal Analysis

If the handwheel/pinion shaft assembly has a structural natural frequency in the range of the excitation frequencies which cause accelerations at this location, the accelerations applied to the handwheel due to the pressure fluctuations in the RHR piping could be amplified, resulting in higher vibrations occurring at the handwheel.

The handwheel natural frequency can be determined most accurately by a ring test, in which the handwheel is struck and the resulting vibrations measured by an accelerometer. This can be done during the next outage if desired. In lieu of ring testing, the natural frequency is estimated analytically in Attachment E.2 using a simple analysis technique and estimated configuration and weights. Attachment E.2 concludes that the natural frequency can vary between about 80 Hz to 200 Hz. This range overlaps the 5X frequency range that has been observed at Hope Creek. Based on this simple analysis, the possibility exists that the handwheel and pinion gear assembly has a structural natural frequency in the range of the typical vane passing frequencies experienced at Hope Creek.

This result may also explain why in past years the pinion shaft has been found "sheared" as described in the history data listed above. If the historical record is correct in stating that these pinion shafts have failed in shear (statements that cannot be verified this long after the fact), then it lends support to the theory that the handwheel is being subjected to high vibration loads as these loads would be applied perpendicularly to the shaft, resulting in shear type loads.

It is also possible that the F060 valve geometry is such that the valve "topworks" itself has a modal response at or near the forcing (vane passing) frequency. This is discussed in Attachment E.3. If so, this effect (regardless of whether or not the handwheel has a structural natural frequency that responds to vane passing frequency), would increase the vibration levels experienced at the handwheel.

6.3.6 OE Experience

No operating experience at other plants was identified regarding handwheels on RHR valves. There have been other incidents of handwheels falling off valves at Hope Creek; for example, notification 20098239 was written in May 2002 about a handwheel falling off valve 1BC-HV-F024B.

6.3.7 Summary

Vibration occurring at the handwheel resulted in wear on the hub bearing surface. The loss of metal at the hub eventually resulted in the retaining ring losing its grasp on the hub, at which point the retaining ring fell off. With the retaining ring gone, the handwheel was free to fall off the hub and did so after becoming cocked on the hub (and causing wear) for a period of time.

The vibration resulted from accelerations applied at the F060B valve location due to vane passing of the recirculation pumps exciting the RHR piping. It is possible that the F060B valve topworks, and/or the handwheel/pinion shaft assembly, have a structural natural frequency in the range of the expected vane passing frequencies. If so, the result would be amplified accelerations applied to the valve handwheel, causing increased vibration.

6.3.8 Recommendations

- The handwheels on the F060 valves will continue to experience vibrations due to pump pressure pulsations. Accordingly, to ensure that the observed hub wear (leading to handwheel detachment) does not recur, it is recommended that the following action be taken:
    - Remove the handwheel from the F060A and F060B valves prior to return to power operation following the next refueling outage.
    - If the handwheels cannot be removed, the valve operator/handwheel assembly should be modified. Possible modifications include clamping or welding the handwheel to the hub to assuredly prevent any relative motion of the components that could lead to wear; replacement of the hub and handwheel with wear resistant materials; replacement with a system "tuned" or dampened so as to minimize the effect of vibration; or replacement with a motor operated valve designed for the expected acceleration levels.
- The amount of relative motion between the handwheel and the hub that led to the wear seen in March 2004 has not been determined. It may be a very slight movement, repeated for a large number of cycles. In this case, simply lashing the handwheel in place using lockwire may not be sufficient to prevent this slight relative movement. The hubs and handwheels on the F060A and F060B valves should also be inspected during the next refueling outage to see if tightly securing the handwheel with lockwire as was done in Spring 2004 was sufficient to prevent recurring wear.

6.4 F060A and F060B Limit Switch Failures

6.4.1 Description of Limit Switch Hardware

The nominal design of the F060 valve limit switch hardware is shown in Figure 6-4 and consists of the following components:

- The indicator rod. This is a ¾" diameter, 8" long rod that is threaded on both ends for a length of 3". The bottom of this indicator rod threads into a hole tapped 1.5" deep into the top of the block valve stem.

- The limit switch finger. The finger is clamped between two nuts threaded onto the top threaded end of the indicating rod. The finger extends through a slot in the stem protector subassembly and contacts a limit switch lever arm when the valve is in either extreme of its range. The position of the finger relative to the limit switch lever arm can be changed by adjusting the nuts on the indicating rod.

  The geometry of the fingers installed in the F060A and F060B valves differ, as shown in Attachment A photographs. A search of early plant records shows that the F060B limit switch finger was modified during plant construction (Reference: Startup Deviation Report BC-0951). The configuration of these switches found broken in March 2004 does not match the vendor design for the limit switch finger (Anchor/Darling Valve Company drawing number 152860404).

- The stem protector subassembly. This subassembly is mounted on the gear box cover which in turn is bolted to the top of the F060 valve gear box assembly. The gear box cover supports a half coupling which threads onto the bottom of the stem protector subassembly. The valve stem passes through this half coupling when the valve is opened. The stem protector subassembly consists of a nominal 3.5" diameter pipe (which has an actual OD of 4") which is 19.5" long and is threaded on each end. The pipe is slotted to allow the limit switch finger to extend out to contact the limit switch levers. The limit switch bracket is a plate welded to the stem protector pipe section adjacent to the slot. This bracket plate supports the two Namco limit switches that indicate the position of the valve.

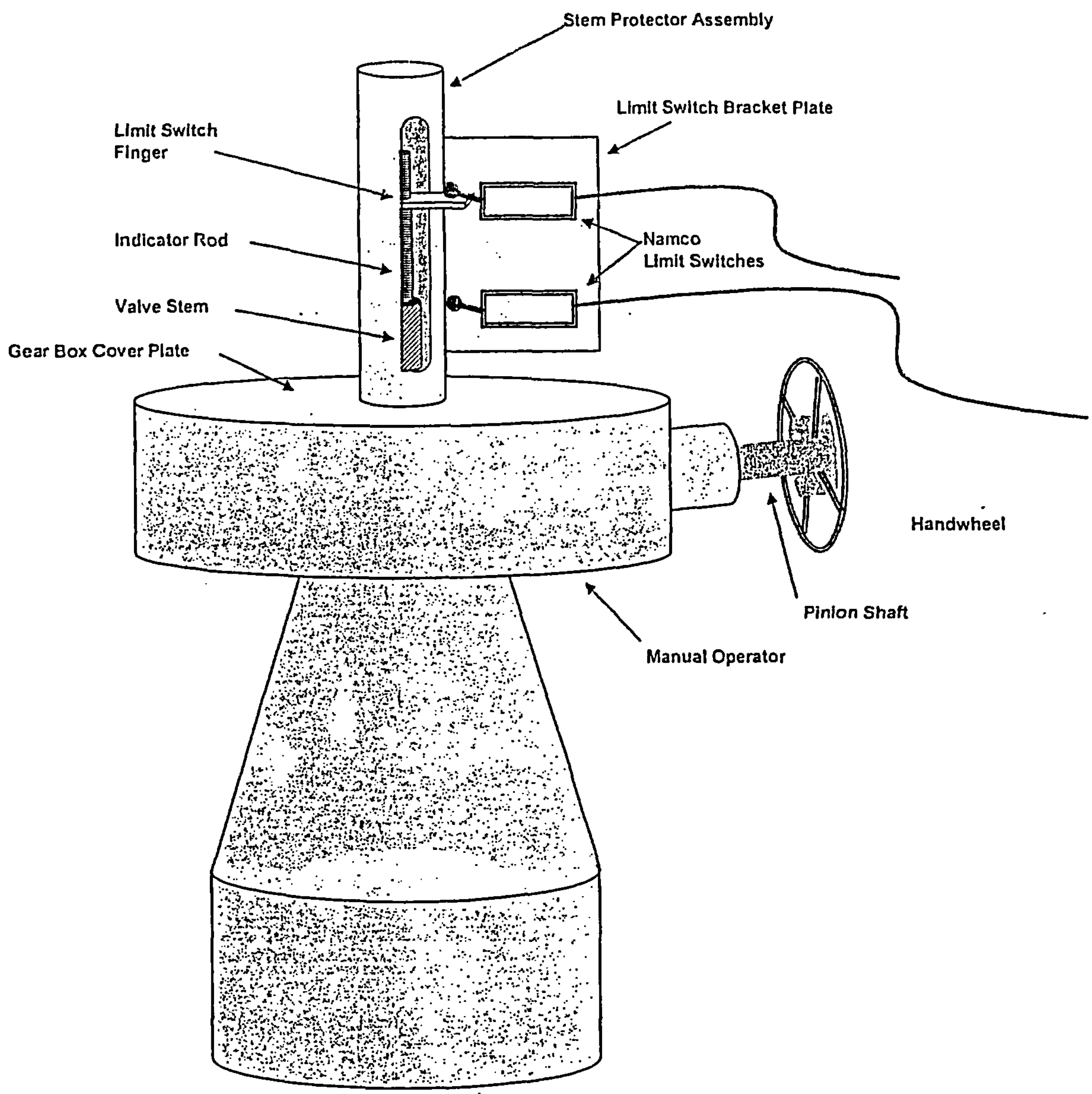


Figure 6-4
F060 Valve Topworks with Limit Switch/Stem Protector Geometry

6.4.2 Current and Past Degradation

During the March 2004 inspection, the following degraded conditions were observed on these limit switches (see photographs in Attachment A):

- The F060A limit switch finger plate was found broken into two pieces. Specifically, the part failed at the 90 degree corner where the piece width increased. Both pieces were recovered and removed from the drywell for inspection.

- The F060B limit switch indicating rod broke off at the point where it threads into the top of the valve stem. In addition, there were deep wear marks where the finger plate contacted the limit switch lever arm, and there was a vertical groove cut into the side of the finger plate. The location of this groove was 2" from the center of the valve stem; this coincides with the diameter of the stem protector pipe at the slot location.

- Photograph A.3-2 shows that there are wear marks on the side of the stem protector slot at the point where the F060A limit switch finger would be when the valve is in its open position.

6.4.3 History

Review of plant data indicates that problems with these limit switches had been experienced before. Table 6-7 summarizes the history of problems found during a search of plant records.

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 adapter 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.
	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.	

Table 6-7

History of F060A and F060B Limit Switch Problems

Valve	Notification	Description of as-found condition	Actions taken
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 gear box 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.	
	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.	

6.4.4 Causal Factor Table

See Attachment F for the causal factor table for the observed degradation. Possible causes considered are thermal expansion of the stem causing contact of the limit switch finger with the stem protector pipe slot, and excitation of the structural resonances of the gear box cover plate/stem protector due to pump pressure fluctuations.

6.4.5 Modal Analysis

The response of F060 valves and attached hardware to piping accelerations can be amplified if the forcing frequency is at or near the structural natural frequency of the valves and/or hardware. As discussed previously, these excitation frequencies are on the order of 7.5-25 Hz and 37.5-125 Hz under normally expected operating conditions. The natural frequencies of the RHR valves and associated hardware are discussed in the following sections.

F060 Valve "Topworks"

The valve vendor provided a design calculation (VTD PP3020-0383) for seismic qualification for the F060 valves which showed that the valve "topworks" (that is, everything above the body-to-bonnet joint) has natural frequencies of 92 Hz and 122 Hz for two modal shapes. These calculated natural frequencies match the 5X vane passing pressure pulsation frequency range of 37.5-125 Hz for typical operation at Hope Creek. This vendor calculation used a simple analysis methodology and nominal valve dimensions and masses as inputs. The vendor used this result to show that the valve topworks natural frequencies are well above the 33 Hz limit typically required for seismic qualification. The simplistic approach used by the vendor to calculate these natural frequencies is adequate for the vendor's qualification purposes, but is not sufficiently accurate to be of use in determining whether the topworks have natural frequencies in the vane passing frequency range of interest to this common cause analysis.

To determine the actual natural frequencies for the valve topworks, ring testing would be necessary. In lieu of ring testing, more detailed analysis could provide a usable estimate. Attachment E.3 provides a parametric evaluation of the topworks based on simple scaling and geometry estimates, and concludes that the frequency of the topworks is likely to be in the range of 100-200 Hz. Accordingly, it is possible that the vane passing frequency range can excite the valve topworks at its natural frequency. If so, the valve topworks will experience accelerations which are amplifications of the accelerations acting at the piping.

F060 Valve Limit Switch Subassemblies

To determine the natural frequencies of the limit switch hardware and the surrounding stem protector, modal analyses were performed of each assembly. This required construction of computer models for each assembly. To create these models, the geometry of each assembly was determined from vendor drawings, from measurements taken from the failed components removed from the drywell, and by scaling several dimensions from photographs. Attachment E.4 summarizes the inputs used in these models.

The models created in this effort are shown in Figure 6-5 below. Note that the model of the limit switch indicator rod and finger modeled the stem in the position that it would be in when the valve is full open. The computer program ANSYS used these models to determine the natural frequencies of each of these components.

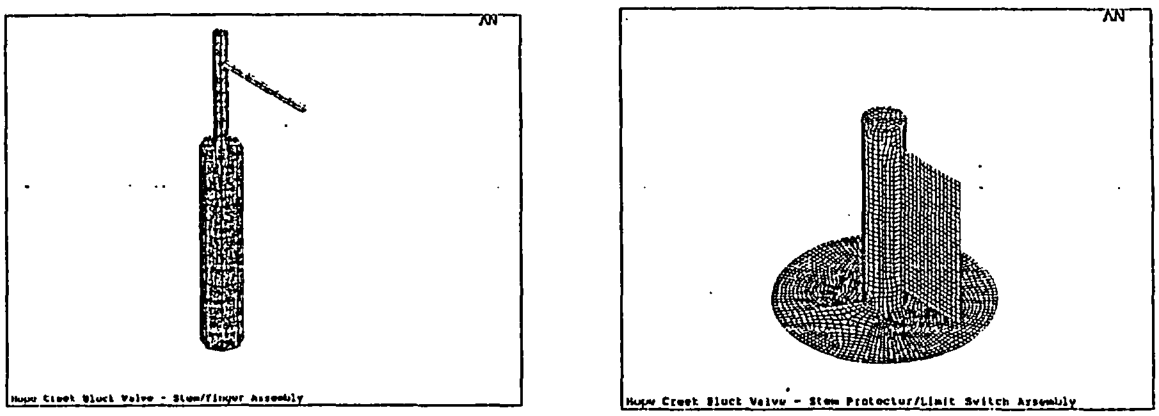
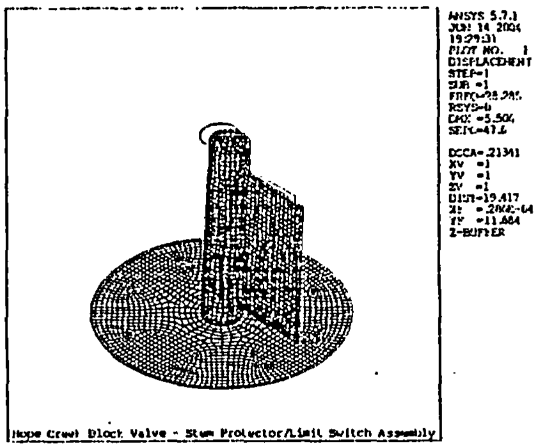


Figure 6-5
ANSYS Models Used to Determine Mode Shapes of F060 Valve Limit Switch/Stem Protector Geometry

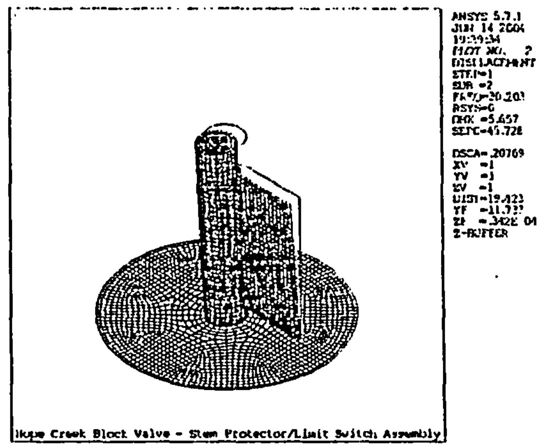
The analysis results showed that the limit switch rod and indicating finger have natural frequencies well above the highest expected 5X vane passing frequency. Accordingly, the indicating finger and stem rod will move as the stem itself moves, with little or no amplified relative motion.

The gear box cover plate and stem protector pipe have several natural frequencies and mode shapes in the frequency range of the expected pressure pulsations, as shown in the Figure 6-6 and described below:

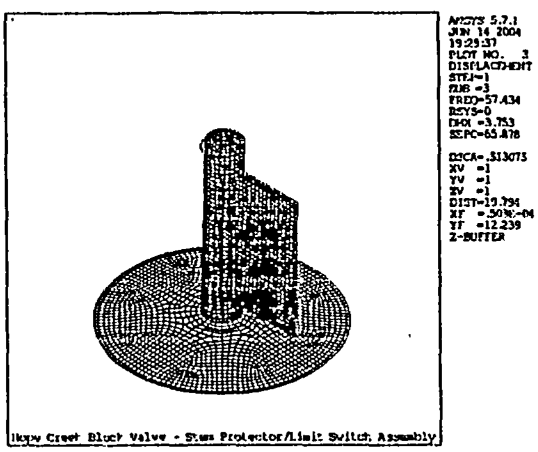
- Mode 1 occurs at 28 Hz. In this mode, the top of the stem protector pipe moves relative to the stem, in the plane of the limit switch bracket plate.
- Mode 2 occurs at 30 Hz. In this mode, the top of the stem protector pipe moves relative to the stem, in the plane perpendicular to the limit switch bracket plate.
- Mode 3 occurs at 57 Hz. In this mode, the cover plate itself deflects up and down, causing the stem protector pipe section to rise and fall. The pipe also tilts relative to the stem in this mode.
- Mode 4 occurs at 138 Hz. In this mode, the plate attached to the stem protector wags from side to side, causing the stem protector pipe to tilt relative to the stem.



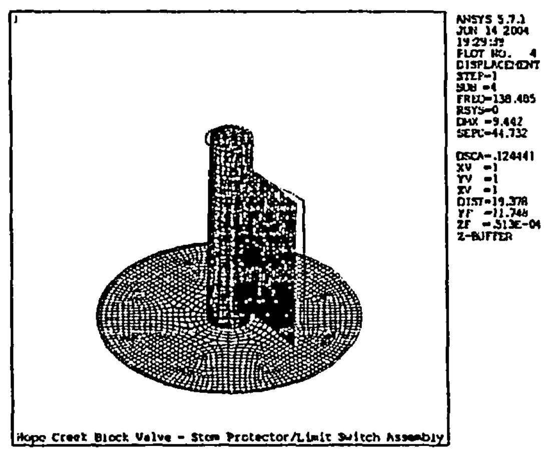
Mode 1 Displacement



Mode 2 Displacement



Mode 3 Displacement



Mode 4 Displacement

Figure 6-6
Modal Displacement Shapes for Gear Box Cover Plate and Stem Protector Assembly

All four of these motions cause relative motion between the stem and the stem protector slotted pipe. If this motion is large enough to close the gap between the indicating finger and the side of the slot, the resulting contact force could cause fretting of the side of the indicating finger, and bending loads on the finger and on the linkage connecting the finger to the top of the stem.

6.4.6 Metallurgical Analysis of F060A Limit Switch

Attachment D is a metallurgical evaluation of the failed limit switch from the F060A valve prepared by Maplewood Testing Services. The report concluded that the limit switch failed due to a fatigue mechanism. The failure surface showed beach marks which are indicative of fatigue. The failure started at a corner notch at a reduction in cross section with sharp angles, where a stress concentration existed.

The metallurgist reviewed the condition of the failed F060B limit switch and concluded that metallurgical analysis was not warranted due to the poor condition of the piece. Consequently, no analysis has been performed to date of the failed F060B limit switch finger retrieved from the drywell in March 2004.

6.4.7 OE Experience

OE experience review did not reveal similar problems at other plants. As a check, contact was made with the recirculation system engineer at Nine Mile Point Unit 2 (NMP2), to see if that plant has experienced similar problems with limit switches in this system. Like Hope Creek, NMP2 is a boiling water reactor equipped with reactor recirculation pumps providing drive flow to in-vessel jet pumps; however, the two plants differ in that the NMP2 recirculation pumps can operate only at two speeds, whereas the Hope Creek pumps can vary in speed over a wide range. The NMP2 system manager did not recall any similar limit switch problems at that plant.

Engineering evaluation H-1-BB-CEE-1830 noted that there have been repeated limit switch failures of the 20' block valve in the RHR supply piping inside containment (Valve 1BC-HV-F077). The vendor drawing for this valve shows a similar limit switch arrangement.

6.4.8 Review of Degradation Observed

Broken pieces studied from the most recent failures (in March 2004) revealed fatigue damage (per the Maplewood report) of the F060A limit switch finger and signs of fretting and wear of the F060B limit switch finger. The damage appears to be due to contact of the side of the fingers with the wall of the stem protector pipe, at the point where the finger protrudes through the slot. This is evident by the wear seen in the photograph of the F060A valve stem protector, and by the groove cut into the side of the F060B finger (at a position coinciding with where the finger would contact the slot). In addition, it is noted that in October 2001, the F060B gear box cover plate cap screws had to be replaced (see Table 6-7). The notification does not state why this was done, but loosening or damage to these cap screws would be expected if the system is vibrating as described.

Based on the above, it is concluded that there is relative motion between the stem protector and the limit switch finger which results in the stem protector and finger contacting each other. The fact that fretting has occurred on the F060B finger, and the fact that the F060A finger metallurgical analysis found beach marks, indicates that the contact is repetitive.

Further, the modal analysis reported above indicates that the stem protector has several mode shapes in the pump running speed frequency range that would excite the stem and cause it to move relative to the finger. The finger and indicator rod do not appear to have a mode that is excited at these frequencies.

All these facts point to vibration as the cause of the damage to the limit switch fingers.

The vibration-induced failures of the limit switch indicating rods and fingers appear to have started in 2003. Prior to that, limit switch problems for these valves were related to cable issues. These may also have been caused by vibration, but at this time this assumption cannot be confirmed. Extensive review of plant data did not reveal any operating conditions which have changed that could explain why the failure mode has changed. It may be that a slight change in recirculation pump speed, or a change to an acoustic property of the recirc/RHR piping, has acted to cause a structural resonance at a frequency that causes the stem protector assembly to move relative to the finger.

6.4.9 Summary

The F060A and F060B limit switch failures are likely caused by motion of the stem protector assembly which leads to repeated contact and fatigue of the limit switch fingers. The stem protector assembly likely has a natural frequency response in the range of expected vane passing frequencies, which results in amplification of the accelerations acting at the RHR pipe at this location. In addition, the F060 valve topworks may also have a natural frequency in this range.

6.4.10 Recommendations

- Confirm the assumption that the F060 valve topworks and/or stem protector assembly have modal responses at frequencies within the expected range of the pressure pulsations occurring in the piping system. This can be determined by finite element modeling or by ring testing using spare parts or the actual equipment during the next refueling outage.

- Pressure pulsations will continue to occur. If these components have modal responses in the pressure pulsation frequency range, modifications will be needed to prevent recurrence of damage. Specifically, the natural frequency of the F060A and F060B valve topworks and/or stem protector should be changed to avoid the pressure pulsation frequency range.

- To prevent damage to the limit switch fingers due to contact with the stem protector assembly, modify the F060A and F060B stem protector design to prevent contact between the side of the slot and the limit switch fingers. This could be done by widening the slot at the point where the finger contacts the open limit switch.

- As an alternative, investigate the acceptability of removing the limit switches and stem protector pipe assembly from each F060 valve. Position control of these valves would then have to be administratively controlled. If acceptable, this alternative would eliminate recurrence of limit switch failures.

6.5 Noise Heard in the North Pipe Chase in March 2004

6.5.1 Description

On March 13, 2004, prior to plant shutdown, plant personnel reported hearing a "banging" noise coming from inside containment when they were in the north pipe chase (Reference: Notification 20182421). Investigation performed following this observation determined that the banging noise was likely coming from the loop "A" RHR return line. This line penetrates containment in the north pipe chase.

During the Spring 2004 outage, investigations concluded that the noise resulted from either motion of the F060A valve handwheel (which was free to rotate between stops on the valve hub, as described in a Tech Issues Evaluation prepared at that time; included herein as Attachment G), or the F050A actuator (which had become detached as documented in H-1-BB-CEE-1830). To prevent recurrence following startup, the handwheel was securely lashed in place and the detached actuator was replaced with a new component.

As documented in the timeline below, in May 2004 the noise reappeared several weeks following restart.

At this time the root cause of the noise has not been established. This section summarizes the apparent cause evaluation, and the actions recommended to finalize determination of the root cause of this noise.

6.5.2 History

Table 6-8 summarizes the events associated with this noise in the form of a timeline:

Table 6-8
Timeline for Noise in North Pipe Chase

Date	Event
5/27/2003	1BCZS-F060B showed a dual indication (Notification 20146178).
10/18/2003	Indication on 10C650A for 1BCZIL-F060A 'A' SDC manual isolation valve has been lost. Light bulbs tested satisfactory. (Notification 20162879)
November 2003	Plant personnel report a noise in the north pipe chase. There is some debate as to its source; then the noise goes away.
3/12/2004	Based on later interviews with personnel, prior to this date there were no reports of any noise heard in the north pipe chase.
3/13/2004	An unusual "clunking" noise, irregular in rhythm, is reported in the north pipe chase (Notification 20182421).
3/18/2004	Amplitude of the noise decreased, but the impacting noise did not stop

Table 6-8
Timeline for Noise in North Pipe Chase

Date	Event
3/20/2004	Framatome sound engineer states that the impacting object is most likely heavy, more than 30 pounds, and is coming from the vicinity of the F050A and F060A valves (H-1-BB-CEE-1830, Attachment B.2).
3/22/2004	During a forced outage, drywell inspection reveals that limit switches have failed on F060A, F060B valves; the actuator for valve F050A has become detached; and the handwheel has fallen off F060B (Notifications 20182400, 20182396, 20182395, 20182397).
April 2004	Replacement parts are installed in drywell for F060A, F06B limit switches; F050A actuator; F060B handwheel. Testing by plant personnel suggests that the noise could have been caused by either the F050A actuator or the F060A handwheel. The plant restarted during April.
4/30/2004	No noise heard.
5/3/2004 am	Low rumbling noise reported. Begin core flow increase.
5/3/2004 pm	Banging noise heard.
5/5/2004	Noise recurred. Debate as to whether it was the same as banging noise on May 3.
5/11/2004	Framatome sound engineer indicates that the noise heard is different from the sound heard in March.
5/12/2004	Open indication light lost for limit switch on F060A.
5/12/2004 at 12:45	Framatome sound engineer indicates that the noise heard is similar to the sound heard in March.
5/12/2004 at 15:00	Framatome sound engineer reports that the noise now appears similar to that heard on 5/11/2004.
5/12/2004 at 15:00	Closed indication light came on for limit switch on F060A.
5/12/2004 at 17:00	Original noise (like that heard in March) returns.

6.5.3 Causal Factor Table

See Attachment F for the causal factor table for the observed degradation. Possible causes are addressed in the next section.

6.5.4 Evaluation of Potential Causes

Potential causes include the following:

- F060A Valve Stem Protector Deflection. The stem protector has not previously been investigated as a potential source for the noise. The stem protector is believed to have a natural frequency at or near the full power pump running speed frequency, which could result in amplified motion at certain pump speed conditions. Several of the vibration mode shapes would cause a deflection of the gear box cover plate, or tilting of the stem protector pipe, which could produce a drum-like sound like that being observed. It is noted that each time the noise was first reported, the limit switch indication on the F050A valve developed problems at about the same time; this may indicate that the stem protector is beginning to oscillate. The characteristics of this oscillation would be affected by the presence of the limit switch finger; i.e., once the finger fails, the noise may change in characteristic. This matches the behavior described in the above time line. If this is occurring, the stem protector assembly may exhibit signs of distress (wear marks, loosened cap screws, distortion). As stated later on in Recommendations, the stem protector assembly should be inspected for this type of distress to determine whether this is causing the noise.

- F050A Check Valve Disc Chattering. Valve testing reveals that this valve has a slight leakage (within test acceptance criteria). Accordingly, it is likely that the pressure on either side of the disk has been equalized. Given this condition, the valve disk may be fluttering or moving back and forth in reaction to pipe vibration. This may cause the noise heard in March 2004. However, valve testing performed in the March 2004 outage found the valve to relatively leak tight. This suggests that the valve disk is not banging since such movement would likely degrade the seat or disk and prevent the valve from maintaining a leak tight seal. Also, the system engineer stationed in the pipe chase reported that the sound of the disk closing (following a test) was not the same as that heard in March 2004. To determine whether the F050A valve disk is causing the noise, a recommendation is made below that the condition of this valve be determined at the next refueling outage.

- F050A Check Valve Actuator Banging. The actuator was found detached from its mounting during the March 2004 outage. This component was believed to be a likely cause for the banging noise, based on testing by plant personnel. The actuator was found to have an out-of-tolerance thread condition which was determined to be the cause for its detachment. The actuator was replaced with a similar component verified to have appropriate threads. If this actuator has again become detached, it may again be causing the noise. To determine whether the check valve actuator is causing the noise, a recommendation is made below that the actuator should be inspected at the next refueling outage.

- F060A Knocker Handwheel Banging. Plant personnel determined that the impact of the handwheel against its stops was a possible source of the noise. Plant personnel reportedly secured the handwheel tightly prior to restart following the March 2004 outage. To determine whether the handwheel banging is causing the noise, a recommendation is made below that the handwheel should be inspected at the next refueling outage to determine whether it has loosened.

- F060A Valve Handwheel/Shaft Deflection. The handwheel shaft may be vibrating as a beam and impacting surrounding components in the valve operator. This could be the cause of the sheared shafts reported on the handwheels earlier in the plant life. To determine if the F060A handwheel shaft deflection is related to the source of the noise, the F060A valve operator internals should be inspected for signs of degradation, loose fitting parts, etc., at the next refueling outage.

- F060A Block Valve Disk Banging. In the open position the valve disk is retracted into the neck of the valve hangs from the stem. In this position, the disk is unrestrained and may move due to the piping vibration occurring at this location, and possibly bang into the inside surface of the valve neck. To determine whether the block valve disk is causing the noise, a recommendation is made below that the valve internals should be inspected at the next refueling outage.

It is noted that the noise tends to appear and disappear, and change in characteristic, over time. This may be indicative of a change in whatever is causing the noise to occur. Accordingly, it is recommended that the noise be trended routinely and evaluated when changes occur. For example, whenever changes in noise are observed, the following parameters should be recorded and compared:

- Recirculation pump speed (and differences in operating speed of the A and B pumps)
- Reactor pressure and temperature
- Total core flow
- Core differential pressure
- Jet pump flow
- F060A and F060B limit switch position indication

6.5.5 Summary

The cause of the noise in the north pipe chase has not been identified. This section provides recommendations for further activities. These include inspecting components at the next opportunity, and continued monitoring of the noise to determine if changes in plant conditions (such as recirculation pump speed or core flow) affect the noise characteristics.

6.5.6 Recommendations

- To determine whether the F060A gear box cover plate and stem protector is the cause of the noise, the gear box cover plate and stem protector should be inspected at the next refueling outage to look for signs of distress.

- To determine whether the noise is caused by the F050A actuator, the actuator should be inspected during the next refueling outage for looseness or signs that it has been banging into adjacent components.

- To determine whether the noise is caused by the F060A handwheel, the handwheel should be inspected at the next refueling outage to determine whether it has loosened.

- To determine whether the F060A handwheel shaft deflection is related to the source of the noise, the F060A valve operator internals should be inspected for signs of degradation, loose fitting parts, etc., at the next refueling outage.

- To determine whether possible F050A or F060A valve disk motion is causing the noise, the F050A and F060A valve internals should be inspected for signs of degradation, contact, impact, etc., at the next refueling outage.

- Trend the noise heard in the north pipe chase routinely. Make an audio recording of the current sound and re-record it whenever it appears to change. In addition, whenever changes in noise are observed, the following parameters should be recorded and compared:

    -- Recirculation pump speed

    -- Differences in operating speed of the A and B pumps

    -- Reactor pressure and temperature

    -- Total core flow

    -- Core differential pressure

    -- Jet pump flow

    -- F060A and F060B limit switch position indication

- To positively identify the source of the noise, it may be necessary to visually monitor the area around the F050A and F060A valves using a remotely operated camera.

7 Safety Significance

7.1 Extent of Condition

All components attached or connected to the recirculation system piping or RHR piping in containment are subject to the recirculation pump pressure pulsations. If the attached components have structural natural frequencies within the pressure pulsation frequency range, then the components are likely to experience vibration at the associated frequencies.

Based on the results in Section 6, it is likely that some of the RHR valve components and small bore pipe lines in the original system design have (or did have) natural frequencies in this range. This indicates that the original plant design did not guard against this phenomenon. Accordingly, there may be other components with similar unfortunate characteristics.

Review of plant operating experience (see H-1-BB-CEE-1830, Attachment A) revealed 13 instances of limit switch failures on the 1BC-HV-F077 valve installed in the RHR supply line in containment. This is a 20" manually operated, locked open valve which per the vendor drawing appears to have limit switch finger plate arrangement comparable to that in the F060 valves. Many of the reported failures appear to be similar to the recent limit switch problems seen on the F060A and F060B valves. This valve is also subject to recirculation pump pressure pulsations and is likely being subjected to the same degradation mechanisms. It is recommended that the modal characteristics of the top works, stem protector and gear box cover plate be determined (either by analysis or test during the next refueling outage) to determine whether these components have structural resonances in the range of pump-induced pressure fluctuation frequencies.

The review did not reveal evidence of other problems. However, it is recommended that during the next refueling outage, the following components be inspected to ensure that there is no obvious degradation occurring that has been missed to date:

- Recirculation pump suction valves 1BB-HV-F023A and 1BB-HV-F023B, and associated hardware (limit switches, handwheels, motor operator components)
- Recirculation pump discharge valves 1BB-HV-F031A and 1BB-HV-F031B and associated hardware (limit switches, handwheels, motor operator components)
- RHR supply line MOV 1BC-HV-F009 and associated hardware (limit switches, handwheels, motor operator components)

- RHR outside containment penetration isolation valves 1BCHV-F008, 1BCHV-F015A, and 1BCHV-F015B and associated hardware (limit switches, handwheels, motor operator components)

Further, it is recommended that all instrumentation lines associated with the recirculation pumps and motors be walked down to ensure the lines are adequately supported.

7.2 Generic Implications

Recirculation piping vibration is a well known phenomenon in BWRs like Hope Creek. However, the damage to hardware seen at Hope Creek has not been reported elsewhere as an area of concern. It is likely that plants planning to make changes to their recirculation pump operating conditions (for example, plants considering increasing pump speeds due to uprate or replacing constant speed pumps with variable speed pumps) will experience the same issues.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

Degradation seen in March 2004 in components in the recirculation and RHR piping systems at Hope Creek is believed to have resulted from vibration. This common cause analysis report summarizes results of investigations into the cause of the vibration and the resulting degradation, and the noise heard in the pipe chase.

Vibration Analysis

In order to understand the vibration and its affect on the plant equipment, PSEG Nuclear implemented a vibration monitoring program and recorded vibration data at various plant power levels as the plant restarted following the March 2004 outage. Results of that vibration monitoring program are evaluated herein, and are as follows:

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

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

- Acoustic and structural resonances are present in the piping system. When the pump pressure fluctuation frequency matches these resonant frequencies, the resulting piping vibrations increase in magnitude. The vibration levels monitored during the testing are acceptable from the standpoint of the large bore piping stresses but may contribute to the degradation observed to valve components seen in March 2004.

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

Analysis of Degraded Conditions

The effect of this vibration has been to cause degradation of components in the RHR piping inside containment; specifically, hardware connected to certain RHR valves. This report also explores the individual degraded conditions that stem from this common cause. Key results for each degraded condition are as follows:

- <u>Detachment of the F050A actuator</u>: The actuator was subject to pipe accelerations due to pump-induced pressure fluctuations which caused the actuator cylinder to sway back and forth. This in turn caused relative motion of the male and female threads where they contact each other in the threaded joint connecting the cylinder to its casting support, leading to thread wear and increased clearances. As the clearances increased, the magnitude of the resulting relative motion increased, leading to accelerated wear. This continued until the thread clearances opened up to the point where there was little overlap in the threaded joint. As this occurred, retention force for this joint shifted to the cap screw installed for anti-rotation. The tip of the cap screw gradually wore off due to continue relative motion, permitting the cylinder to slide down the casting until it finally fell off.

- <u>Detachment of the F060B valve handwheel</u>. Vibration occurring at the handwheel resulted in wear on the hub bearing surface. The loss of metal at the hub eventually resulted in the retaining ring losing its grasp on the hub, at which point the retaining ring fell off. With the retaining ring gone, the handwheel was free to fall off the hub and did so after becoming cocked on the hub (and causing wear) for a period of time. The vibration resulted from accelerations applied at the F060B valve location due to vane passing of the recirculation pumps exciting the RHR piping. It is possible that the F060B valve topworks, and/or the handwheel/pinion shaft assembly, have a structural natural frequency in the range of the expected vane passing frequencies, resulting in amplified accelerations applied to the valve handwheel and increased vibration.

- <u>Limit switch failures of the F060A and F060B valves.</u> The F060A and F060B limit switch failures are likely caused by motion of the stem protector assembly which leads to repeated contact and fatigue of the limit switch fingers. The stem protector assembly likely has a natural frequency response in the range of expected vane passing frequencies, which results in amplification of the accelerations acting at the RHR pipe at this location. In addition, the F060 valve topworks may also have a natural frequency in this range.

- <u>Noise in the north pipe chase.</u> An earlier effort to determine the source of the noise heard in March 2004 determined that the noise originated either from a detached air piston cylinder associated with a check valve in the RHR piping inside containment, or possibly from a loose handwheel on an adjacent block valve. Both of these conditions were fixed prior to restarting the plant in April 2004. However, in May 2004 the noise returned. Accordingly, at this time the cause of the noise has not been positively ascertained. The report investigates possible causes and provides recommendations for validating the actual cause.

The failure of the small bore lines early in plant life, and the recent failures of valve hardware discussed in this common cause analysis, have a common root: an original design of components attached to the Hope Creek recirculation system that did not take into account the fact that the variable speed recirculation pumps at Hope Creek would produce a range of pressure pulsation frequencies that included the component resonance frequencies. This results in vibratory loads on the equipment which over time cause the equipment to degrade due to high cycle wear, fretting or fatigue. The fact that the installed plant equipment has structural resonances at or near the expected pump pulsation frequency ranges indicates that the original plant design did not guard against this possibility. It is noted that due to the variable speed operation of the recirculation pumps, and the wide range of speeds at which they operate, makes it difficult to design equipment with natural frequencies that will not be excited by the wide range of expected pulsation frequencies.

8.2 Recommendations

Specific recommendations made throughout this report are summarized in Table 8-1.

Table 8-1
Recommendations

Report Section	Recommended Action
6.1	Obtain a set of pipe vibration measurements when the pumps operate at speeds above 1500 rpm. The purpose is to determine whether the piping accelerations continue the upward trend seen to date when the pump speed increases from about 1440 rpm to 1500 rpm. NOTE: It is not necessary to continually record vibrations at these higher pump speeds; the purpose of collecting this data is to ensure the vibration is well understood at expected pump speeds.
6.1	Determine the acoustic characteristics of the recirculation system to understand whether acoustics are contributing to the vibration problem and how the system will respond acoustically to planned uprate conditions (needed for plant uprate).
6.2	Modify the F050A valve actuator at the next refueling outage. Modifications to consider are as follows: • Change the actuator natural frequency such that it will not become excited by the expected pump pulsation frequencies. Suggested approaches include stiffening the actuator (by tying it back to the valve body) or changing its length and/or mass. • Prevent relative motion between the cylinder and casting. One suggested approach is to weld the two components together.
6.2	Disassemble the F050A actuator and check the threads and cap screw for signs of degradation at the next refueling outage.

Table 8-1
Recommendations

Report Section	Recommended Action
6.2	Inspect the F050A actuator each refueling outage to ensure that the cylinder has not loosened or become detached. Because the valve will continue to be subjected to pressure pulsations, continued inspection is recommended to ensure that the modification has effectively corrected the problem. If future inspections show that the degradation is not recurring, it may be acceptable to stop doing this inspection.
6.2	Inspect other valves in containment that have the same type of actuator as the F050A valve during the next refueling outage, to ensure that the air piston cylinder has not loosened or become detached: -- H1BC-BC-HV-F050B -- H1BC-BC-HV-F041A/B/C/D -- H1BC-BC-HV-F006A/B
6.3	Remove the handwheel from the F060A and F060B valves prior to return to power operation following the next refueling outage. If the handwheels cannot be removed, the valve operator/handwheel assembly should be modified. Possible modifications include clamping or welding the handwheel to the hub to assuredly prevent any relative motion of the components that could lead to wear; replacement of the hub and handwheel with wear resistant materials; replacement with a system "tuned" or dampened so as to minimize the effect of vibration; or replacement with a motor operated valve designed for the expected acceleration levels.
6.3	Inspect the hubs and handwheels on the F060A and F060B valves during the next refueling outage to see if tightly securing the handwheel with lockwire as was done in Spring 2004 was sufficient to prevent recurring wear.
6.4	Determine whether the F060 valve topworks and/or stem protector assembly have modal responses at frequencies within the expected range of the pressure pulsations occurring in the piping system. This can be determined by finite element modeling or by ring testing using spare parts or the actual equipment during the next refueling outage.
6.4	Modify the F060A and F060B valve topworks and/or stem protector natural frequency avoid the pressure pulsation frequency range during the next refueling outage.
6.4	Modify the F060A and F060B valve stem protector design during the next refueling outage to prevent contact between the side of the slot and the limit switch fingers. This could be done by widening the slot at the point where the finger contacts the open limit switch.
6.4	Investigate the acceptability of removing the limit switches and stem protector pipe assembly from each F060 valve.

Table 8-1
Recommendations

Report Section	Recommended Action
6.5	Inspect the F060A and F060B gear box cover plate and stem protector at the next refueling outage to look for signs of distress.
6.5	Inspect the F050A actuator during the next refueling outage for looseness or signs that it has been banging into adjacent components.
6.5	Inspect the F060A handwheel at the next refueling outage to determine whether it has loosened.
6.5	Inspect the F060A and F060B valve operator internals for signs of degradation, loose fitting parts, etc., at the next refueling outage.
6.5	Inspect the internals of valves F050A and F060A during the next refueling outage for signs of degradation, contact, impact, etc.
6.5	Trend the noise heard in the north pipe chase routinely. Make an audio recording of the current sound and re-record it whenever it appears to change. In addition, whenever changes in noise are observed, the following parameters should be recorded and compared: -- Recirculation pump speed -- Differences in operating speed of the A and B pumps -- Reactor pressure and temperature -- Total core flow -- Core differential pressure -- Jet pump flow -- F060A and F060B limit switch position indication
6.5	Visually monitor the area around the F050A and F060A valves using a remotely operated camera.
7.1	Determine the modal characteristics of the F077 valve top works, stem protector and gear box cover plate (either by analysis or test during the next refueling outage).

Table 8-1
Recommendations

Report Section	Recommended Action
7.1	Inspect the following components during the next refueling outage to ensure that there is no obvious degradation occurring that has been missed to date: • Recirculation pump suction valves 1BB-HV-F023A and 1BB-HV-F023B, and associated hardware (limit switches, handwheels, motor operator components) • Recirculation pump discharge valves 1BB-HV-F031A and 1BB-HV-F031B and associated hardware (limit switches, handwheels, motor operator components) • RHR supply line MOV 1BC-HV-F009 and associated hardware (limit switches, handwheels, motor operator components) • RHR outside containment penetration isolation valves 1BCHV-F008, 1BCHV-F015A, and 1BCHV-F015B and associated hardware (limit switches, handwheels, motor operator components)
7.1	Verify that all instrumentation lines associated with the recirculation pumps and motors are adequately supported.
7.1	Determine the cause of past failures of the 1BC-HV-F077 valve; provide a remedy; and monitor this limit switch indication during the current run cycle.
8.3	Complete effectiveness review as described in Section 8.3

8.3 Effectiveness Review Plans

Effectiveness can be determined in the future by verifying that actions taken prevent recurrence or the degraded conditions. Accordingly, the following actions are recommended for this purpose:

- Inspect the F050A valve actuator to ensure it is not coming loose from the threaded casting. The corrective actions recommended in this report can be considered effective if, after performing these actions, there is no further degradation of this threaded connection.

- Inspect the F060 valves each refueling outage to ensure there are no repeat occurrences of handwheels detaching or shearing off, or of wear on the hubs. The corrective actions recommended in this report can be considered effective if, after performing these actions, there is no further degradation of the handwheels or hubs.

- Monitor the limit switch indication of the F060 valves. The corrective actions recommended in this report can be considered effective if, after performing these actions, there is no further losses of these limit switches.

9 REFERENCES

1. PSEG Procedure NC.CA-TM.ZZ-0003(Z), "Root Cause Evaluation Guideline," Revision 1.

2. PSEG Calculation SC-0223, "Evaluation of the Post-Modification Pipe Vibration of the RR Instrumentation Lines," Revision 0.

3. HC.OP-SO.BB-0002(Q), "Reactor Recirculation System Operation," Revision 48.

4. NRC Information Notice 95-16: "Vibration Caused By Increased Recirculation Flow In A Boiling Water Reactor," March 9, 1995.

5. GE SIL Number 600, "Increased Containment Noise and Vibration at Increased Recirculation Pump Speed," May 15, 1996.

6. Engineering Evaluation H-1-BB-CEE-1830, "Evaluation of Hope Creek In-Drywell Pipe Vibration," Revision 2.

7. General Electric Letter MRT-9527, December 15, 1995, "Task 1.1 Modal Analysis of Hope Creek Recirculation and RHR Piping."

8. General Electric Document GENE -0000-0027-4832-01, DRF-0000-0027-4832, "PSEG Nuclear LLC Hope Creek Generating Station Recirculation & RHR Piping Start-Up Test Criteria," Revision 1 (VTD 326534).

9. Structural Integrity Calculation HC-06-301, "Hope Creek Recirculation System Vibration Data Reduction," Revision 0 (VTD 326747).

10. VibrAlign Report 040555BP, "Evaluation and Vibration Testing of Recirc and RHR Piping Instrumentation," 12-14 May, 2004 (VTD 326560).

11. PSEG Procedure Number TE-SU.BB-332(Q), "Recirculation System Piping Steady State Vibration Surveillance Test," Revision 2, and test records from data collected in 1986.

12. GE document 22A5405AW, "Piping Response, Measurement," Revision 1 (VTD PNO-A12-3331-0002 (1) -03).

13. Atwood & Morrill Drawing 14053-01-H (PSEG VTD PN1-E11-F041-0388).

14. US Atomic Energy Commission Regulatory Guide 1.61, "Damping Values for Seismic Design of Nuclear Power Plants," October 1973.

15. Bechtel Procedure 10855-P-422Q, Technical Specification for Steady State Vibration Testing.

10 EFFECTS ON OTHER TECHNICAL DOCUMENTS

This report was prepared for the specific purpose of providing a common cause analysis of degradation found in March 2004. As a result, this report does not affect any other technical documents.

11 ATTACHMENTS

A Photo Gallery of Degraded Conditions Observed

B Selected Displacement Results from 1991 Vibration Monitoring of Small Bore Lines

C Investigation of Possible Acoustic Natural Frequencies in the Recirculation and RHR Piping

D Failure Analysis of Limit Switch Finger from Residual Heat Removal Gate Valve

E Summary of Analysis Calculations

F Causal Factor Evaluations for Observed Degradation

G Tech Issues Report on North Pipe Chase Noise

12 SIGNATURES

Preparer:	Randolph C Trench, MPR Associates Randolph C Trench	Date: 7/27/2004
Peer Reviewer(s):	John Barkhau	Date: 8/2/04
	Shelly Kugler	Date: 9/28/04
		Date:
Approved :	J Bristi / MT	Date: 9/28/04

Attachment A: Photograph Gallery of Degraded Conditions

The following photographs show damage to plant equipment of interest to this common cause analysis. The photographs were taken in March and April 2004.

The photographs are arranged by component as follows:

A-1: F050A Actuator

A-2: F060B Handwheel and Hub

A-3: F060A Limit Switch

A-4: F060B Limit Switch

A-5: F065D Limit Switch

Figure A-1.1. F050A Actuator

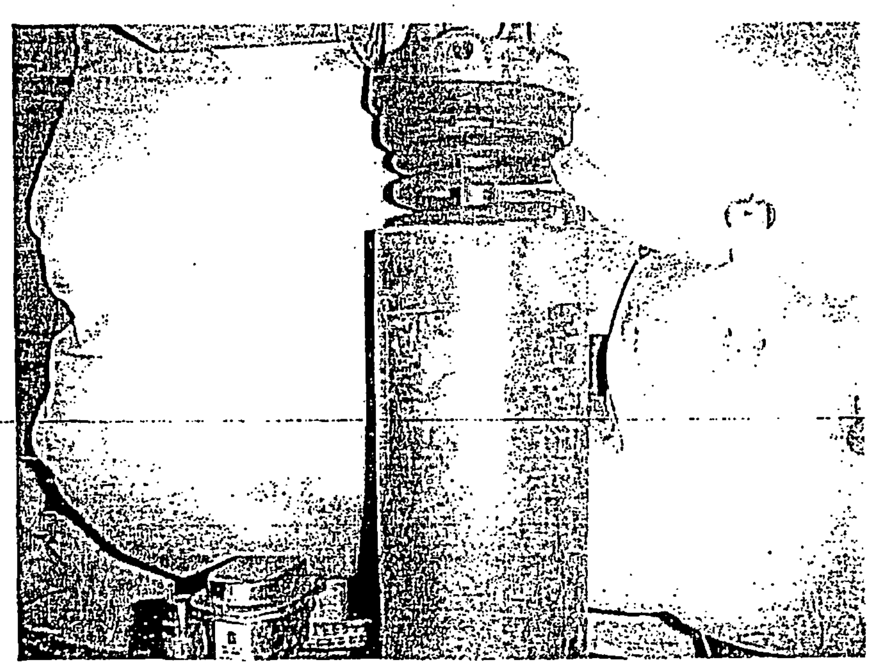


Figure A-1.2. F050A Actuator

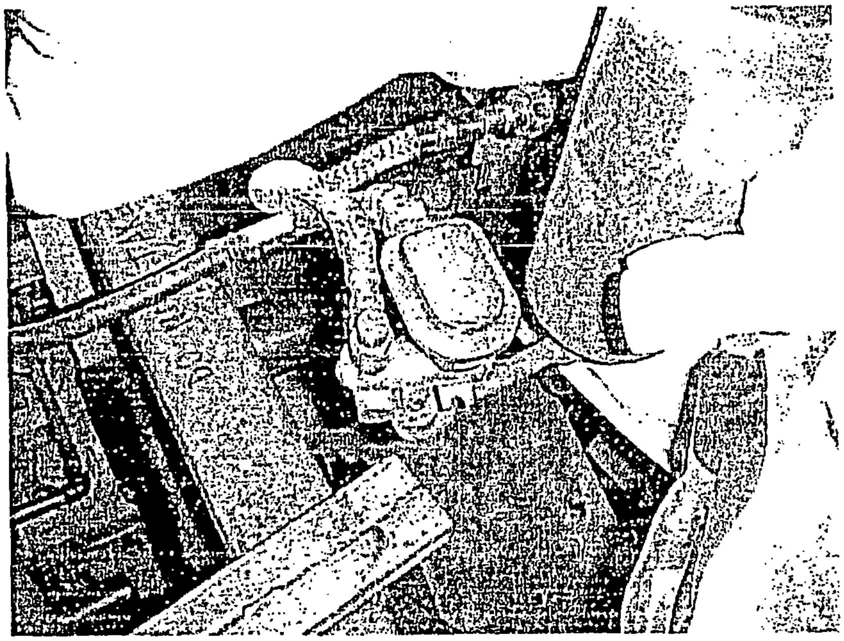


Figure A-1.3. F050A Actuator

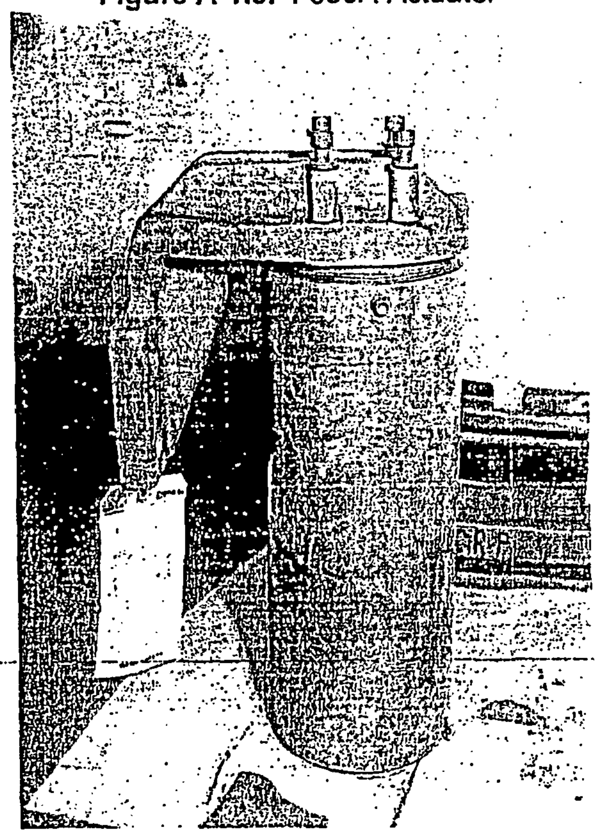


Figure A-1.4. F050AActuator
(This photo shows manipulation of these components performed by engineers during the root cause analysis; it does not depict an as-found condition.)

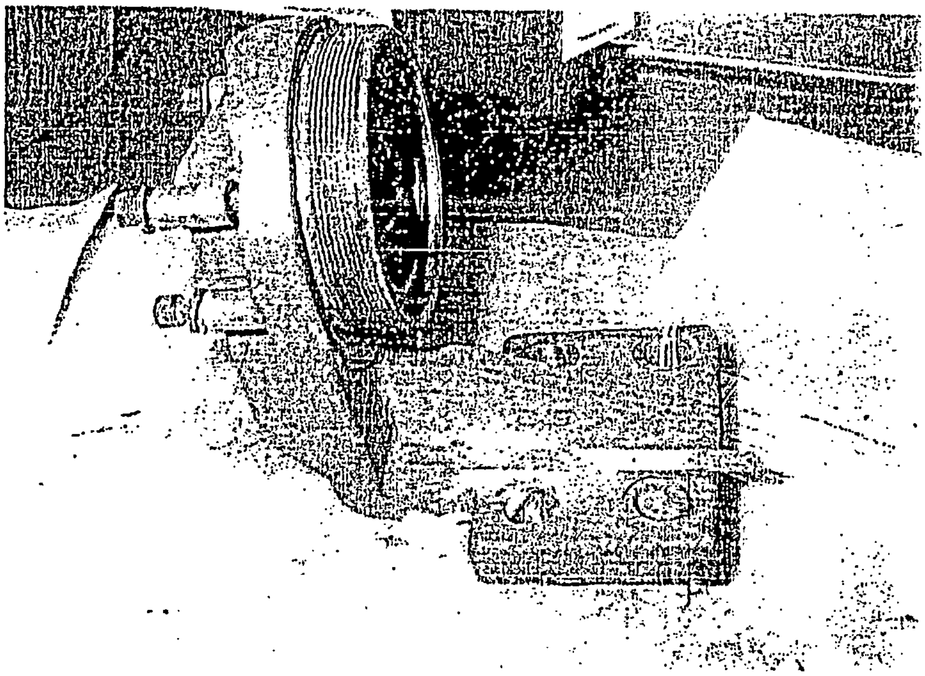


Figure A-1.5. F050A Actuator

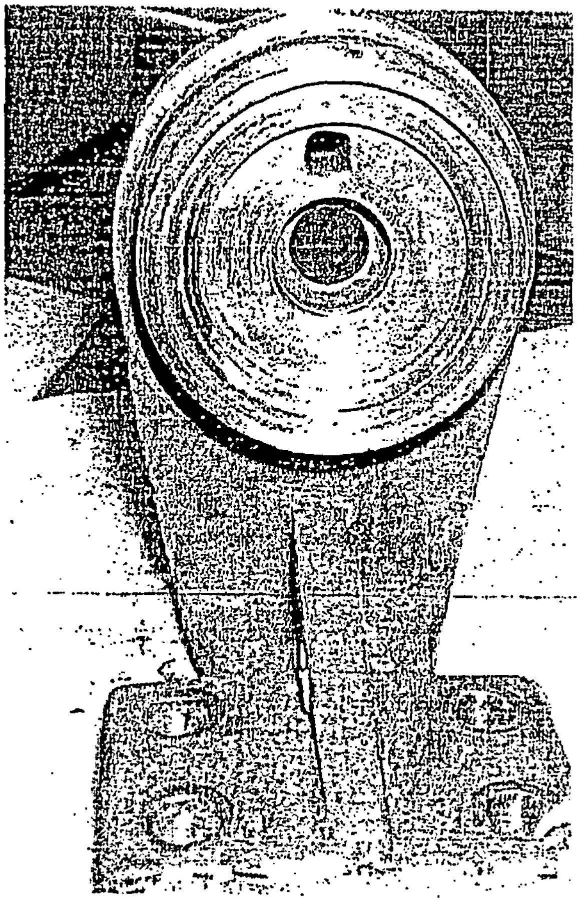


Figure A-1.6. F050A Actuator

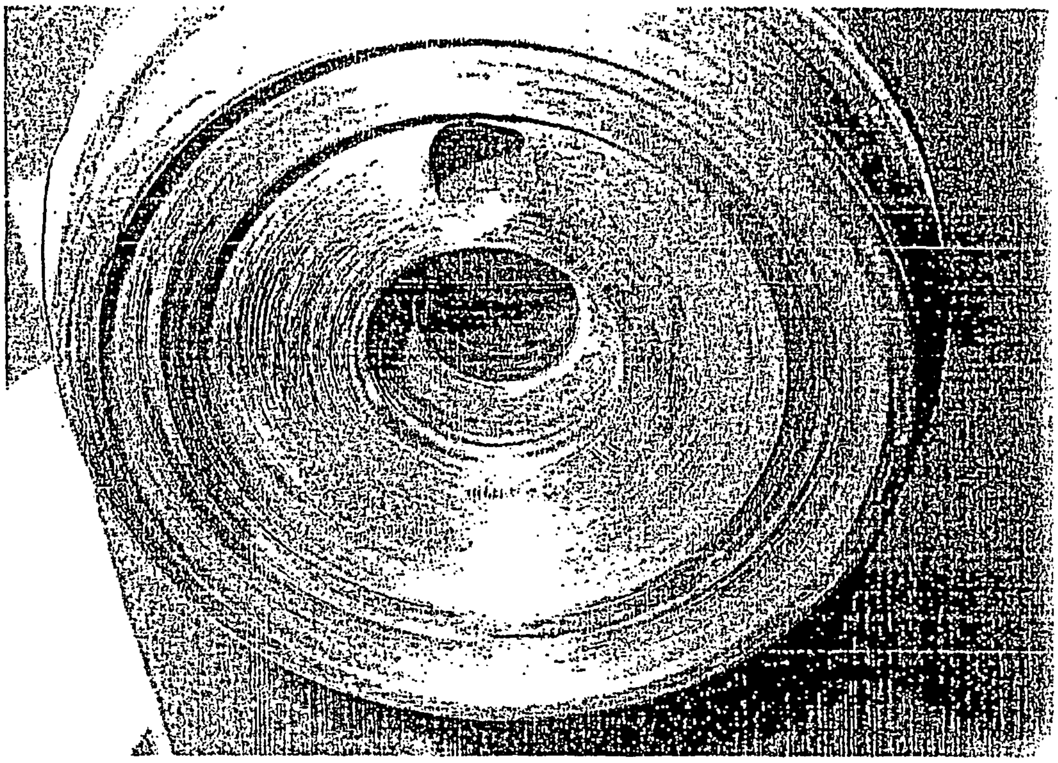


Figure A-1.7. F050A Actuator

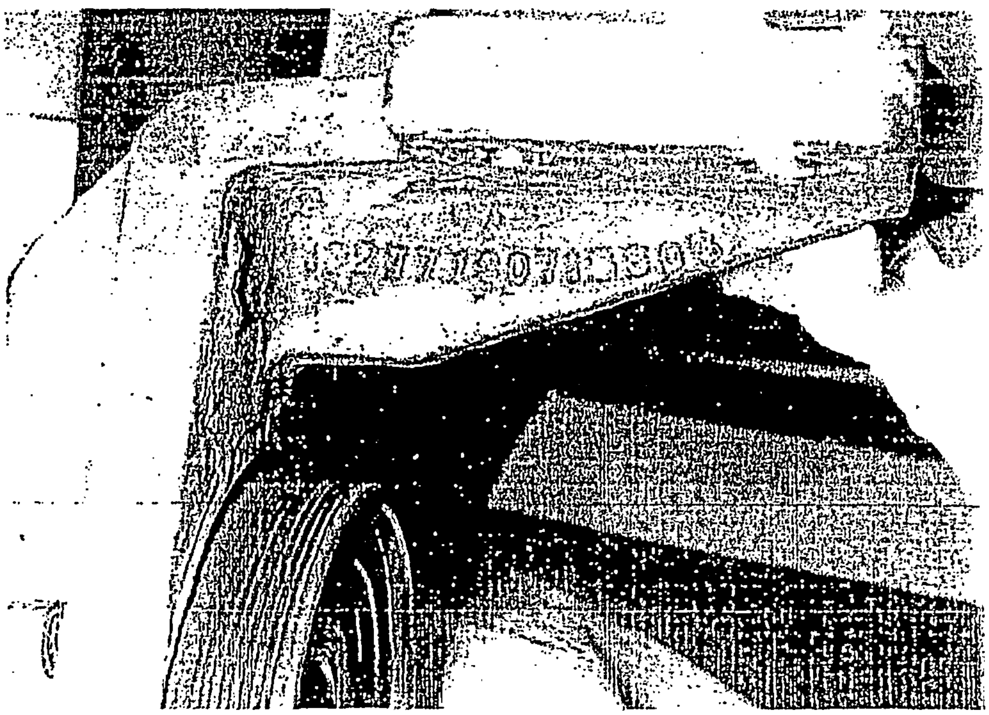


Figure A-1.8. F050A Actuator

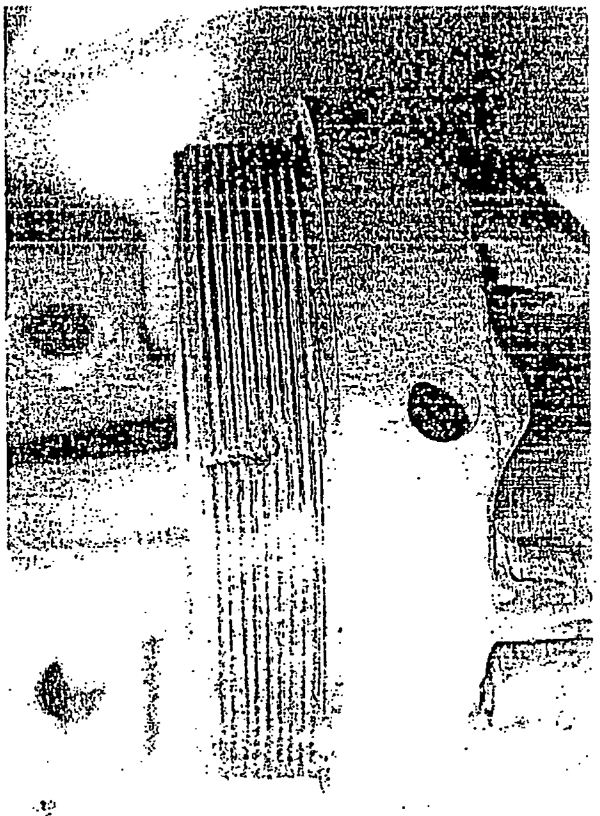


Figure A-1.9. F050A Actuator

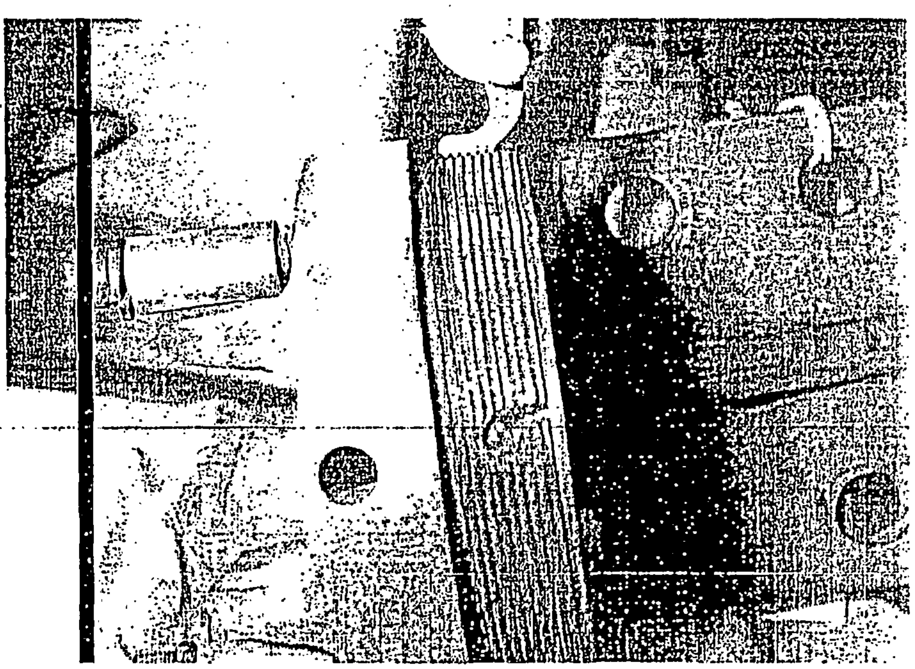


Figure A-1.10. F050A Actuator

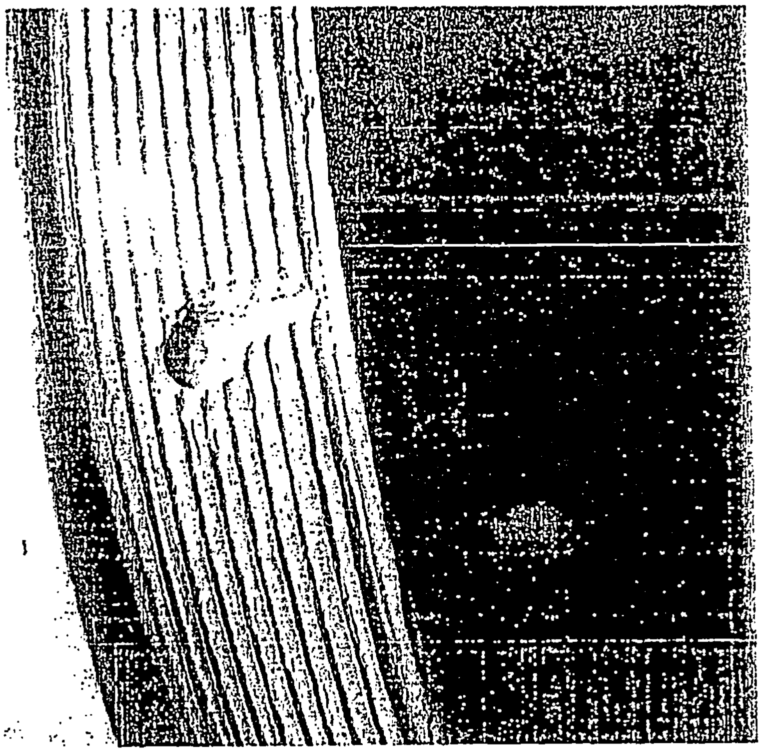


Figure A-1.11. F050A Actuator

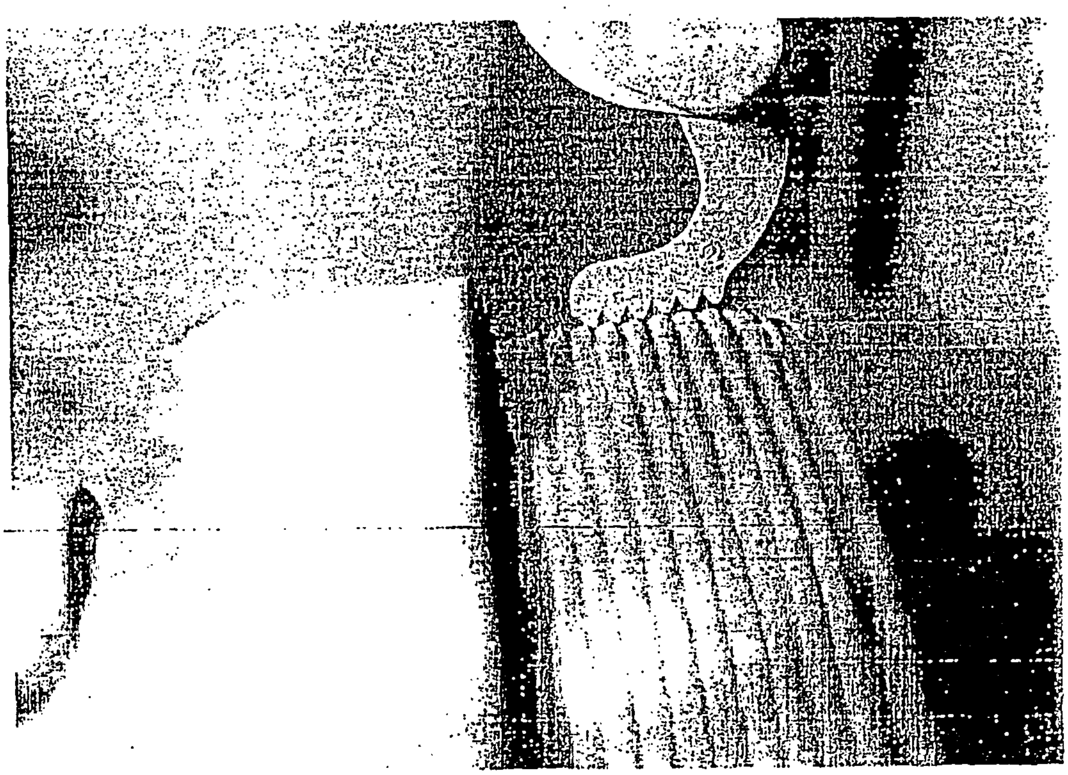


Figure A-1.12. F050A Actuator

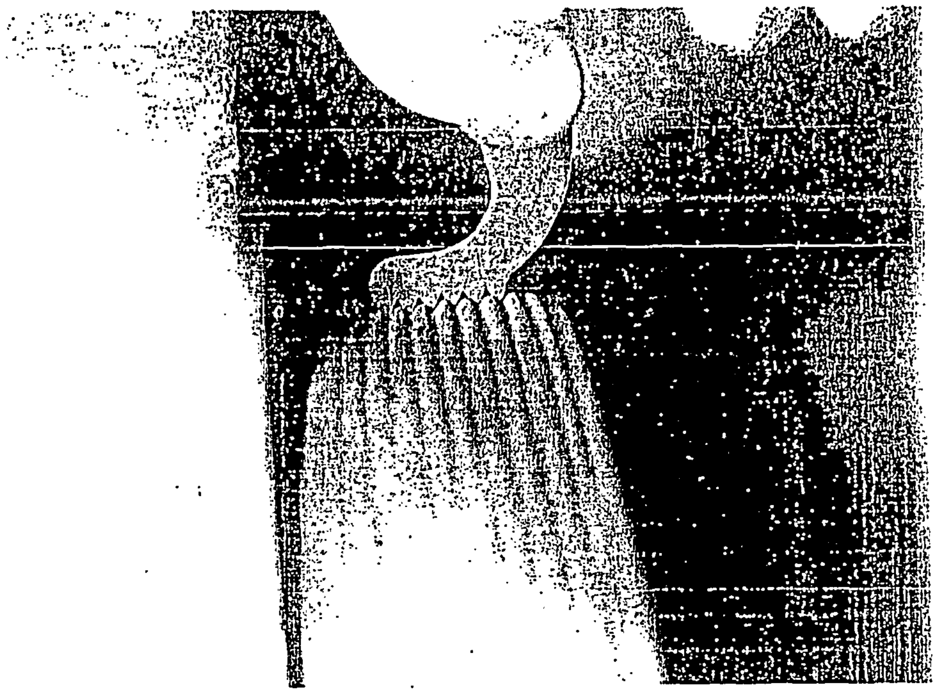


Figure A-1.13. F050A Actuator

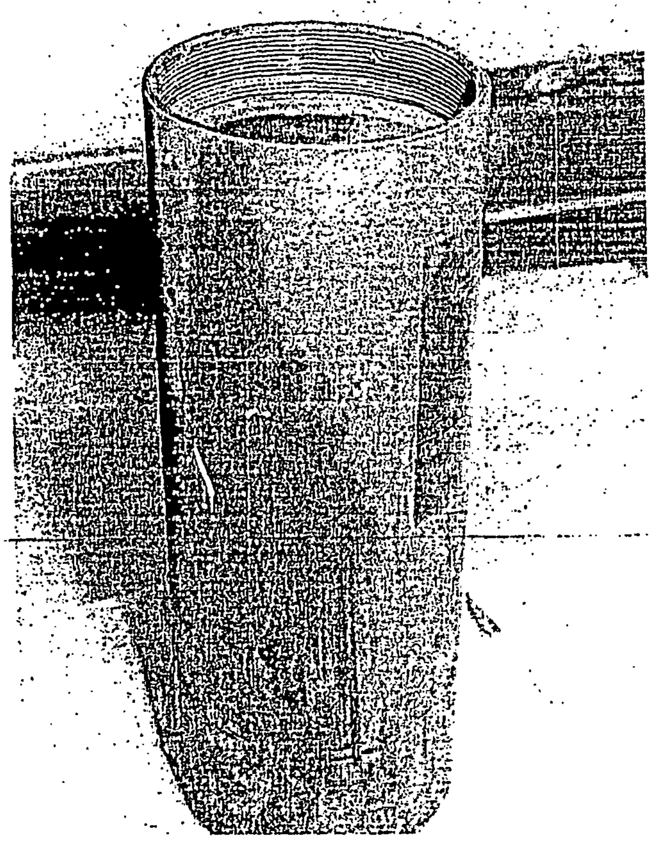


Figure A-1.14. F050A Actuator

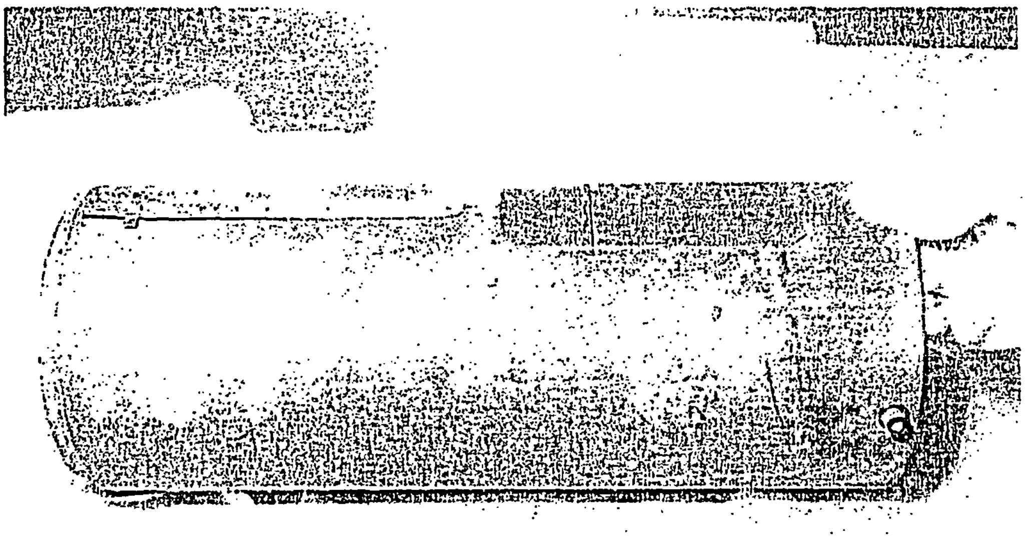


Figure A-1.15. F050A Actuator

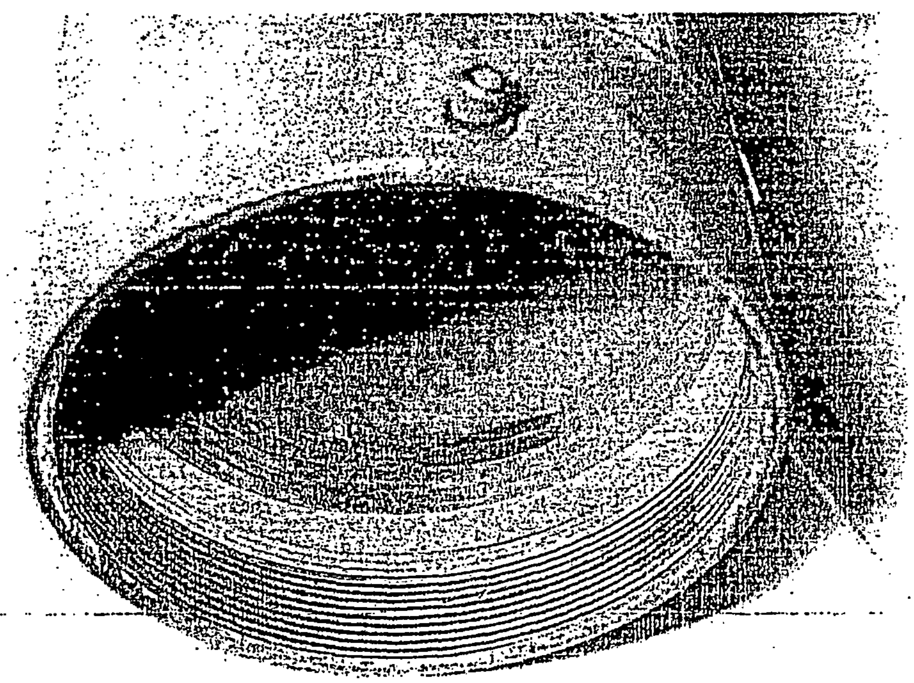


Figure A-1.16. F050A Actuator

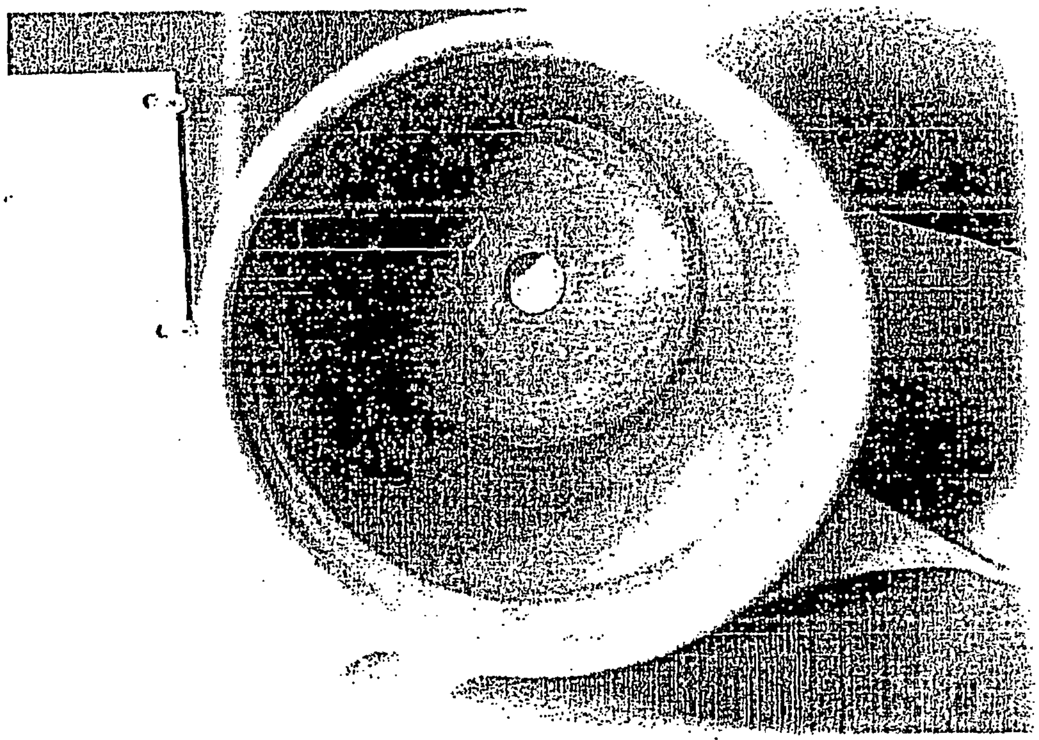


Figure A-1.17. F050A Actuator

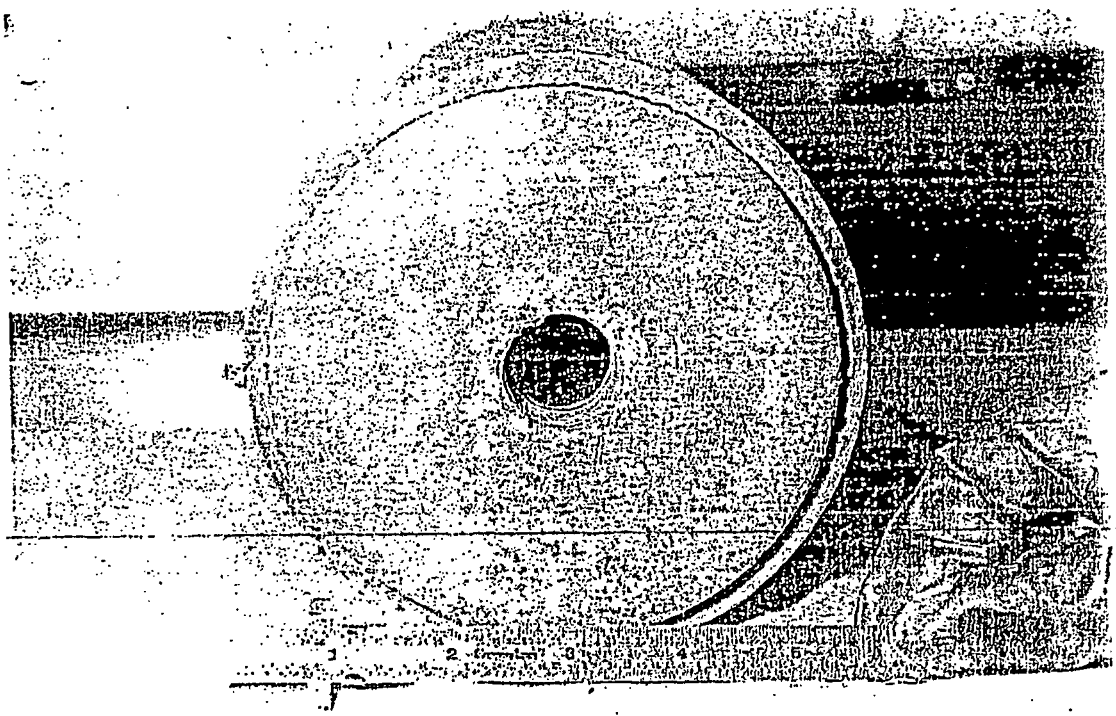


Figure A-1.18. F050A Actuator

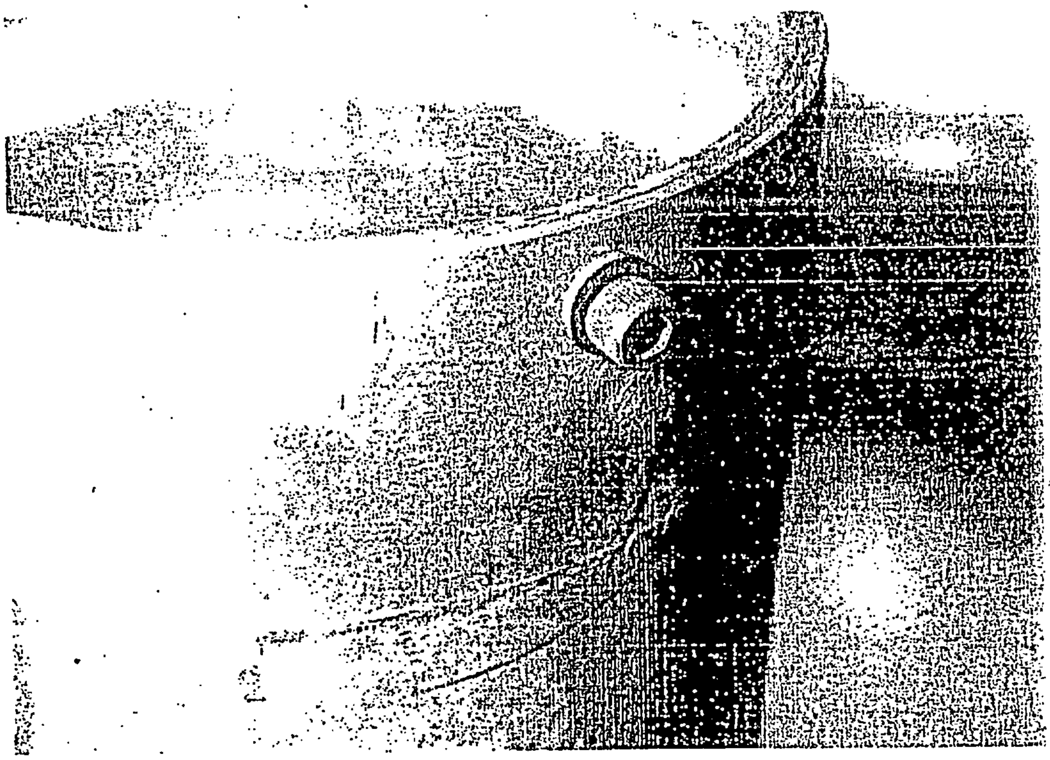


Figure A-1.19. F050A Actuator

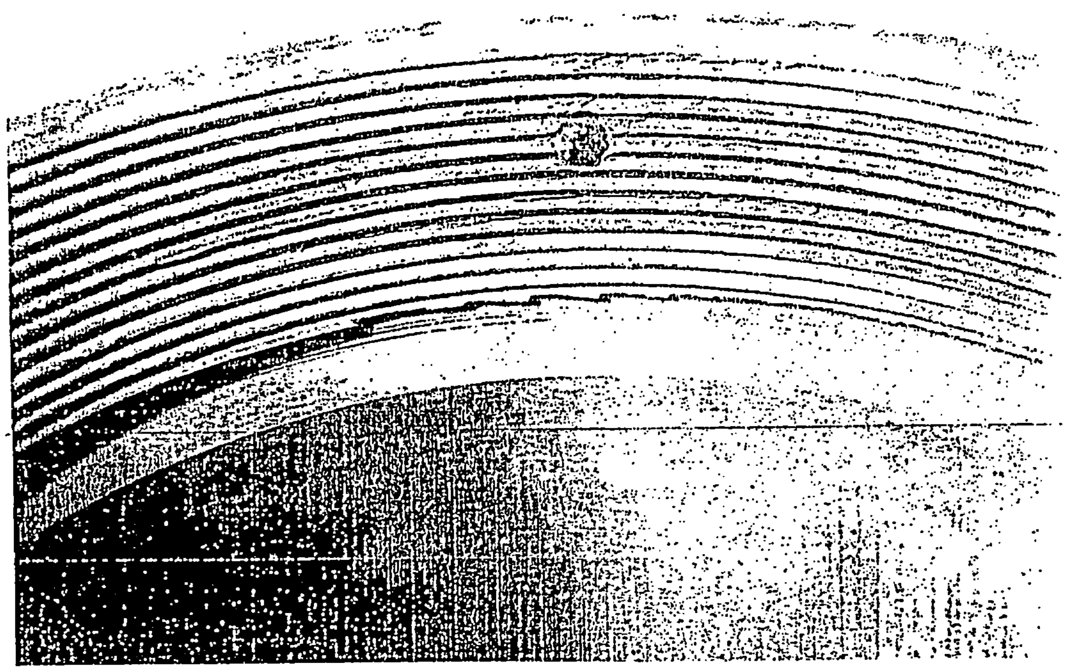


Figure A-1.20. F050A Actuator

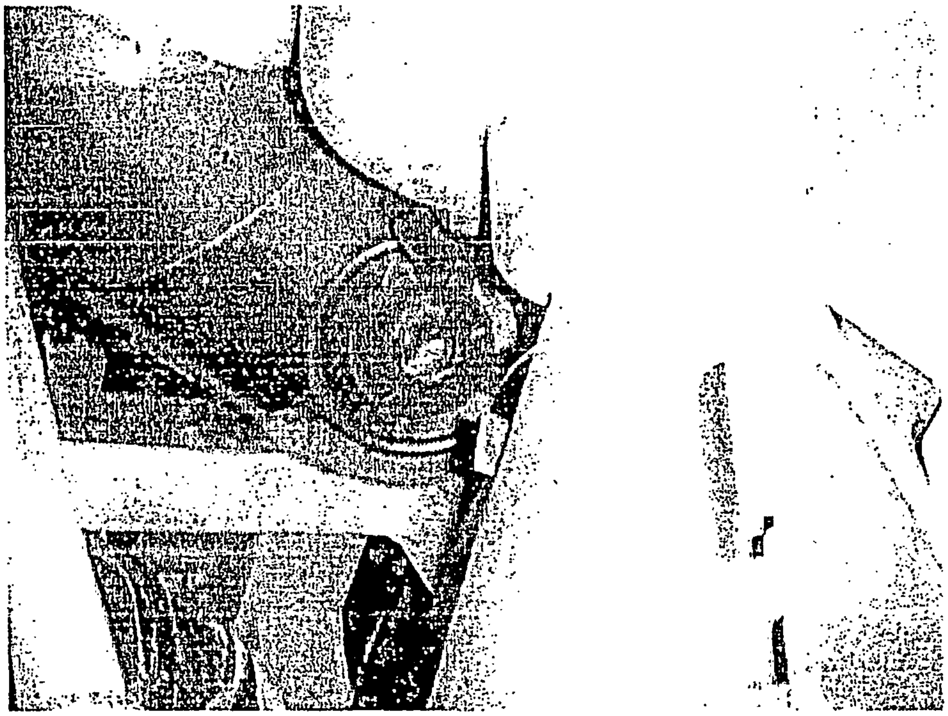


Figure A-2.1. F060B Handwheel and Hub

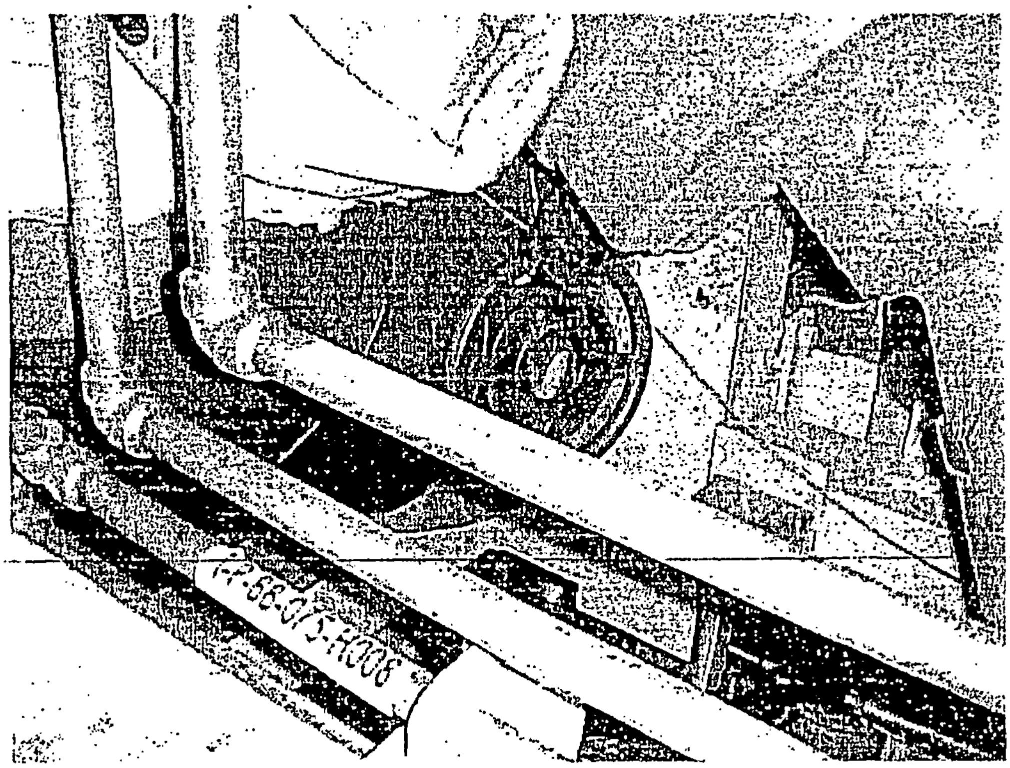


Figure A-2.2. F060B Handwheel and Hub

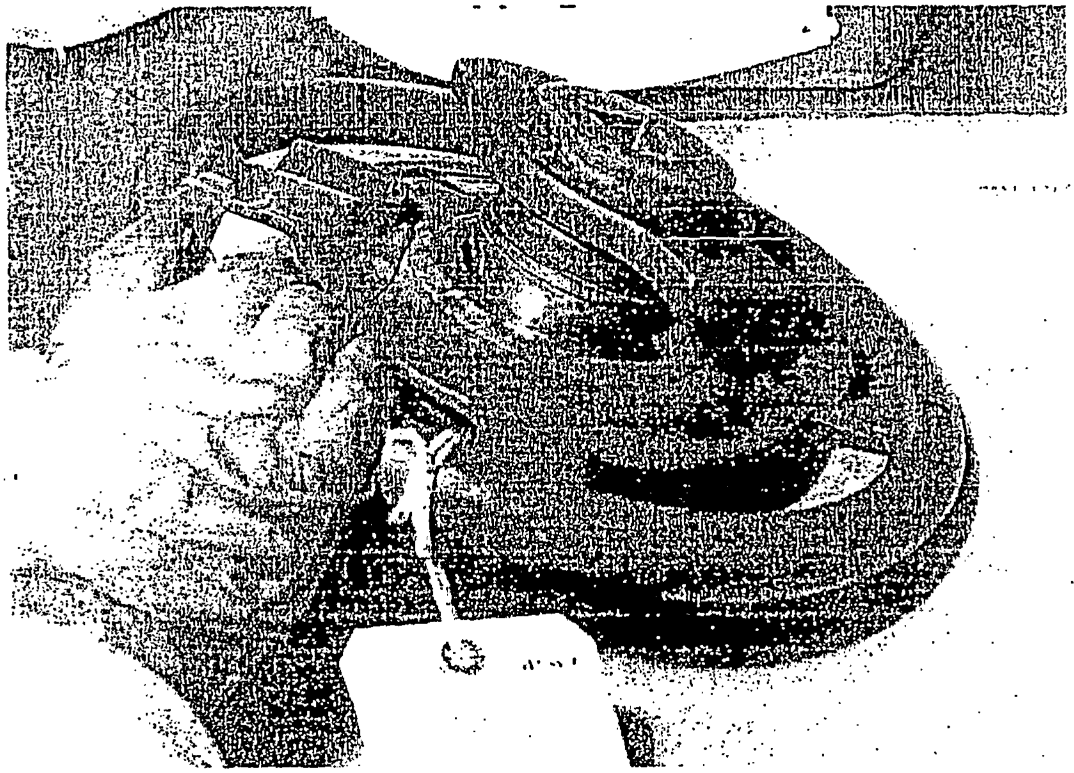


Figure A-2.3. F060B Handwheel and Hub

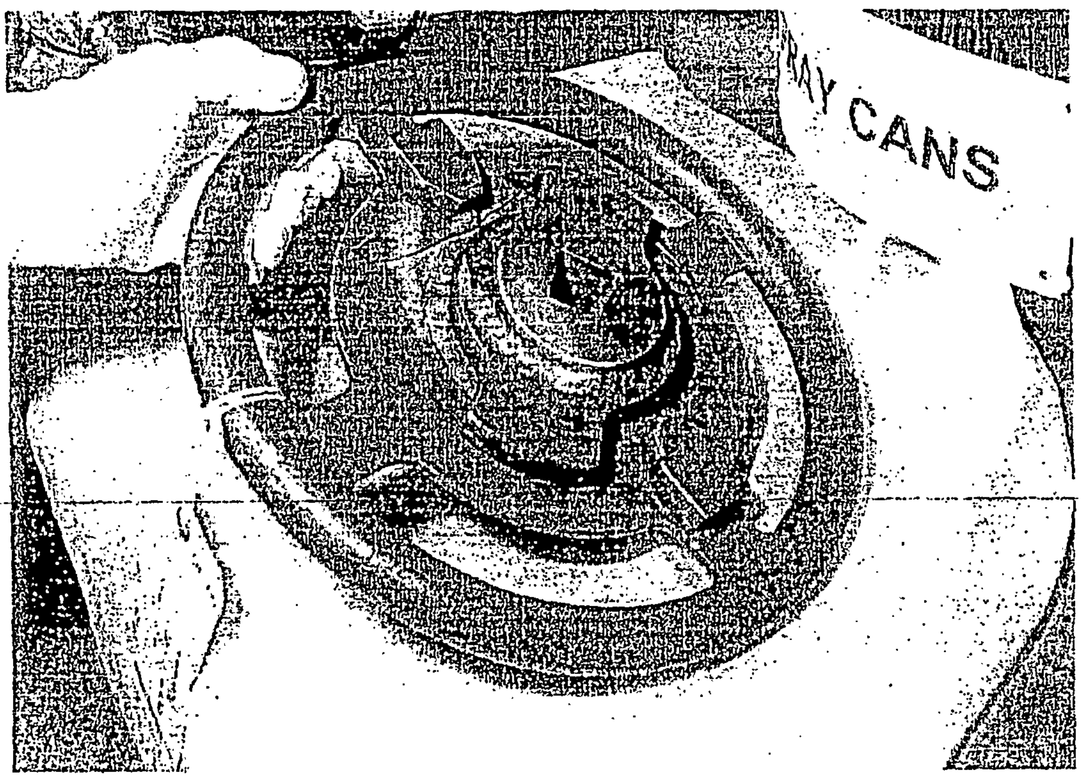


Figure A-2.4. F060B Handwheel and Hub

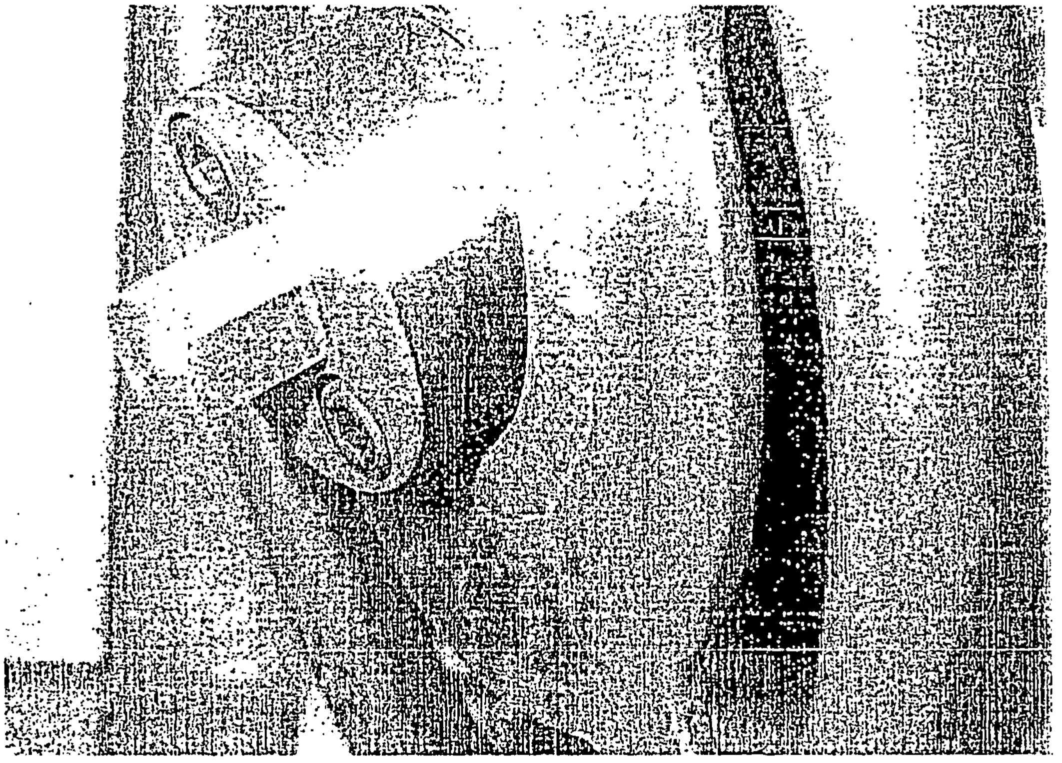


Figure A-2.5. F060B Handwheel and Hub
(This photo shows manipulation of these components performed by engineers during the root cause analysis; it does not depict an as-found condition.)

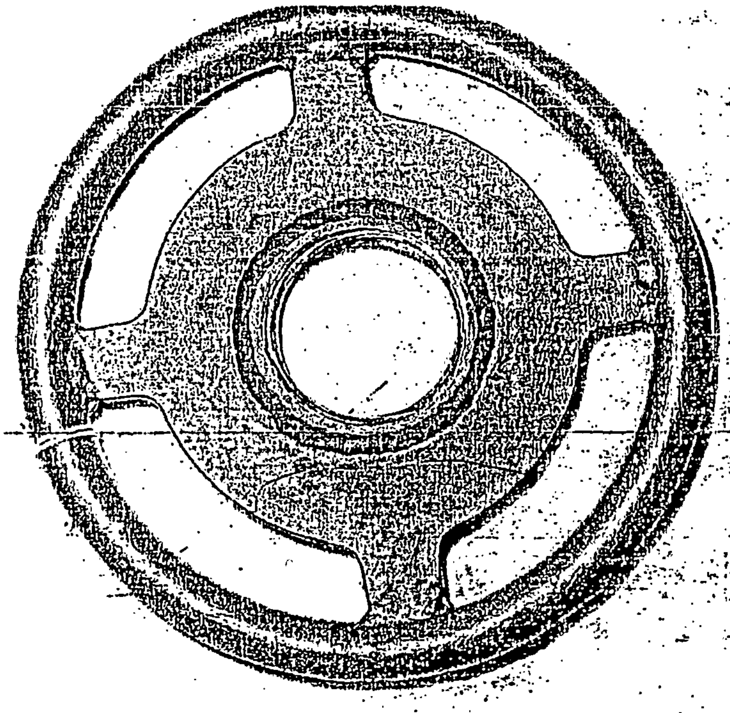


Figure A-2.6. F060B Handwheel and Hub

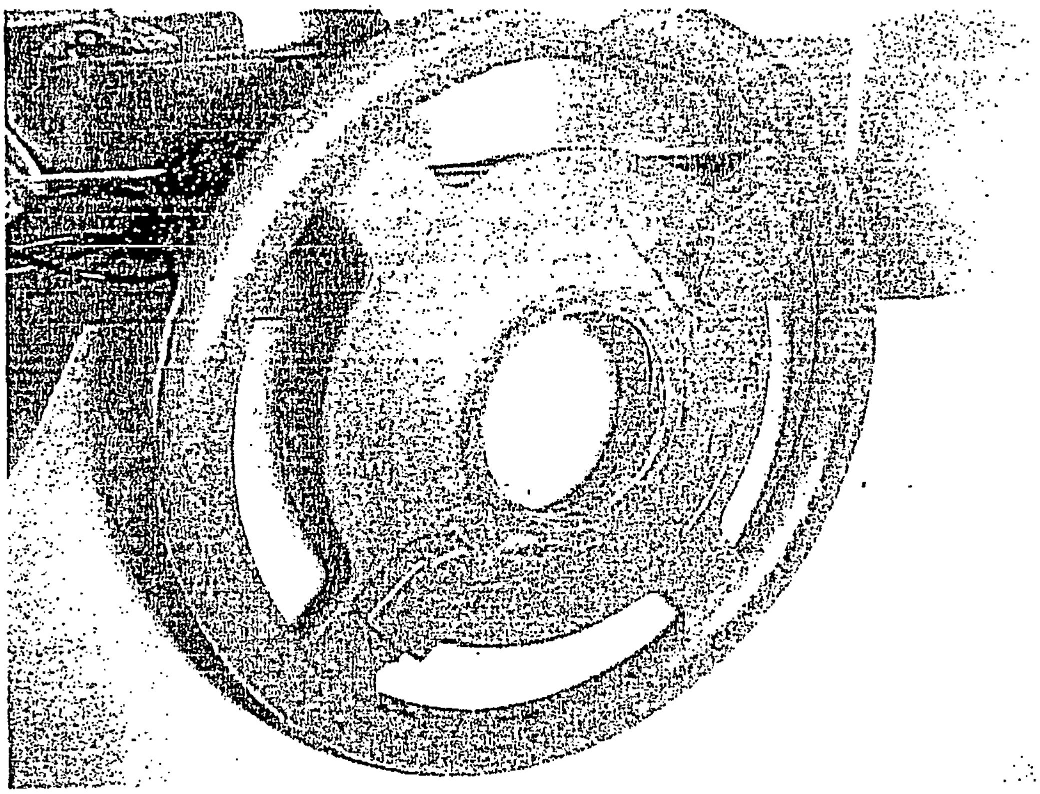


Figure A-2.7. F060B Handwheel and Hub

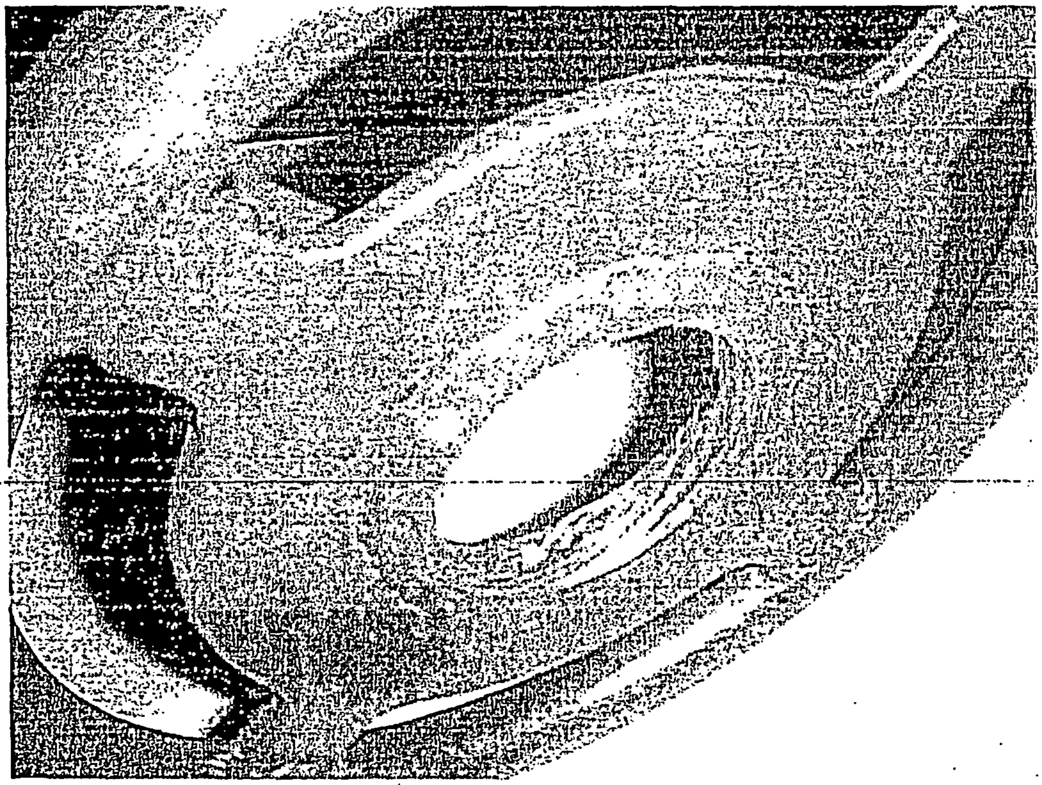


Figure A-2.8. F060B Handwheel and Hub

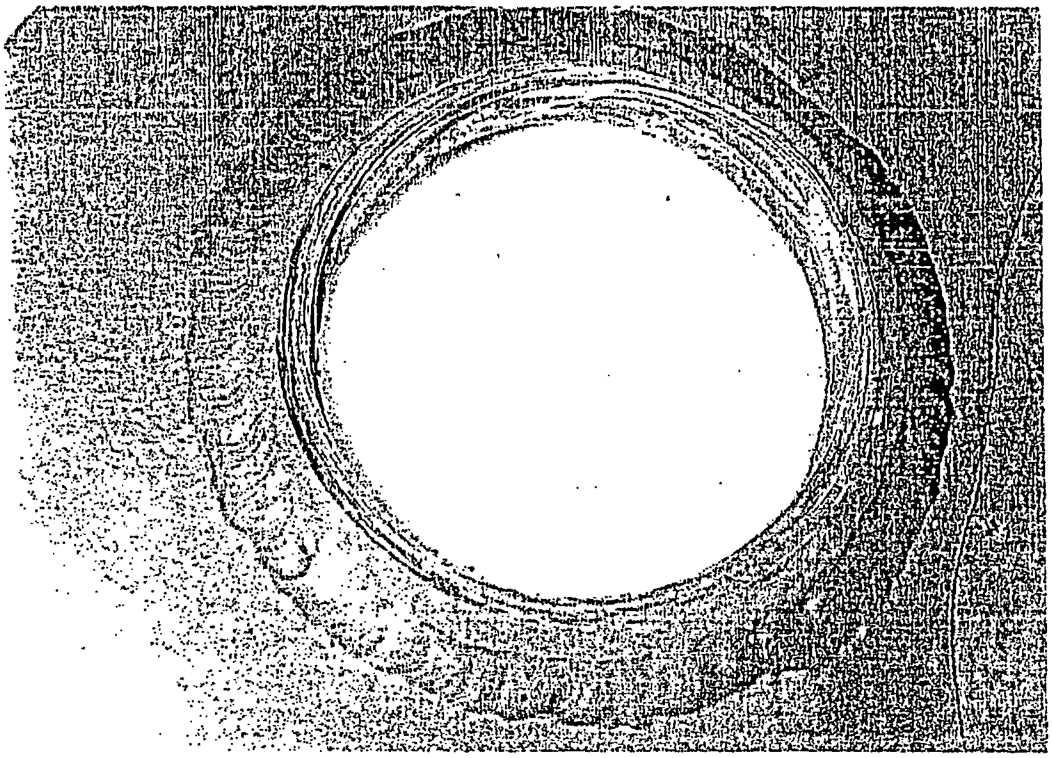


Figure A-2.9. F060B Handwheel and Hub

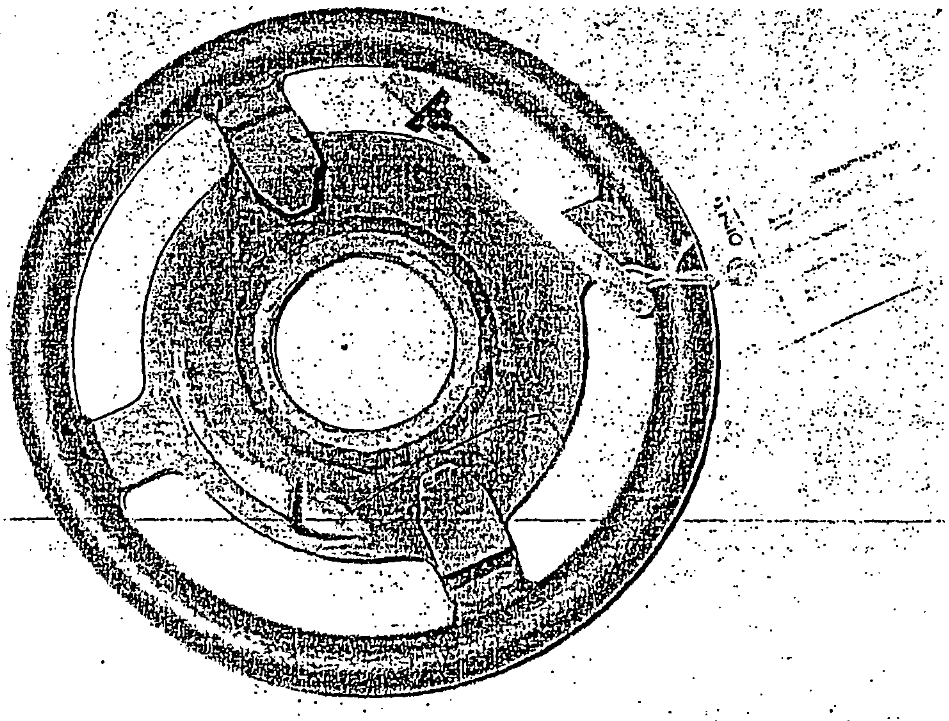


Figure A-2.10. F060B Handwheel and Hub

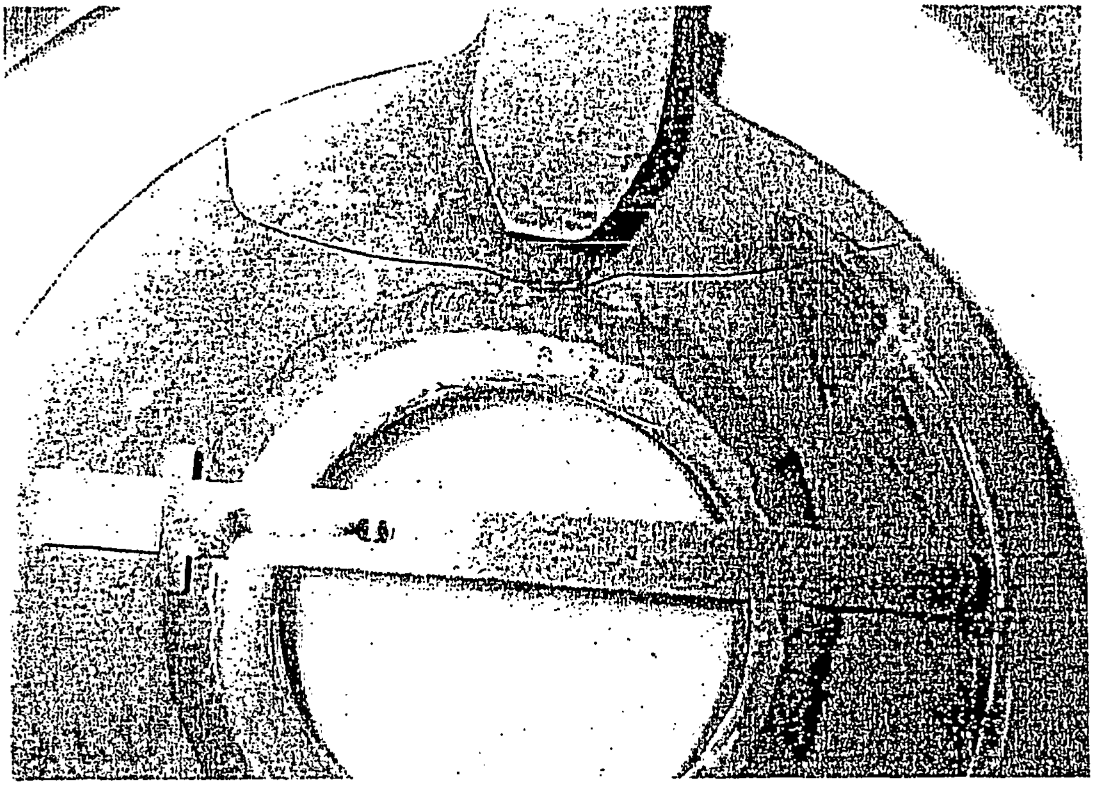


Figure A-2.11. F060B Handwheel and Hub

Figure A-2.12. F060B Handwheel and Hub

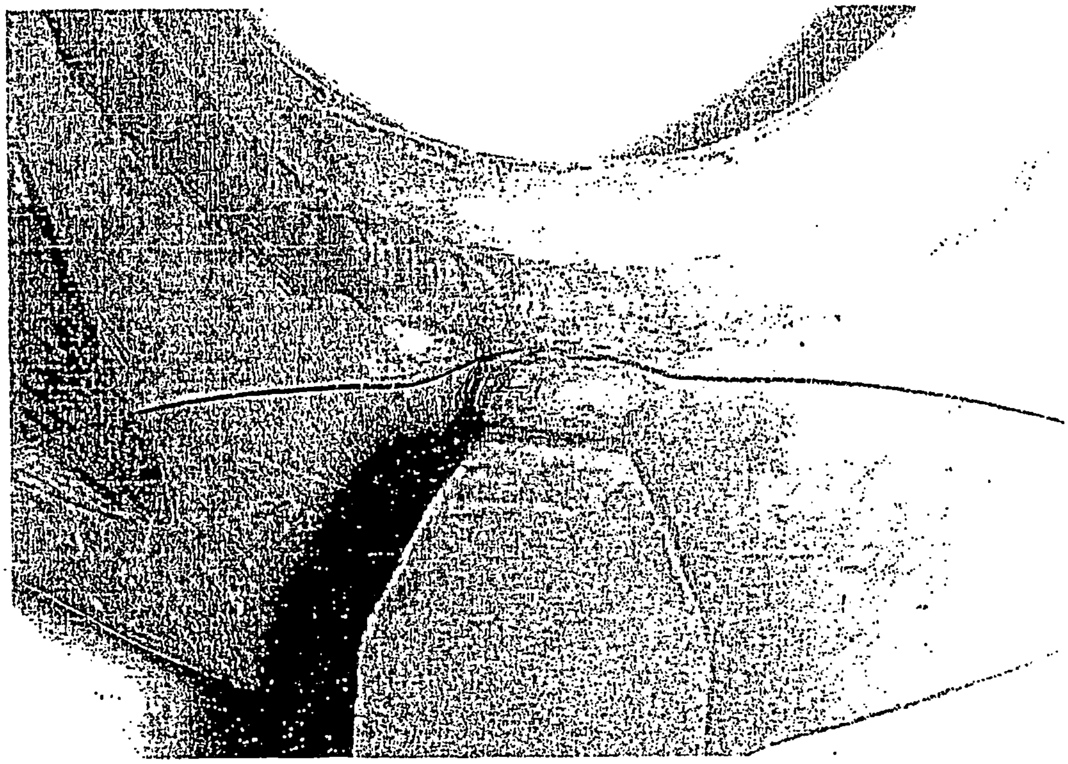


Figure A-2.13. F060B Handwheel and Hub

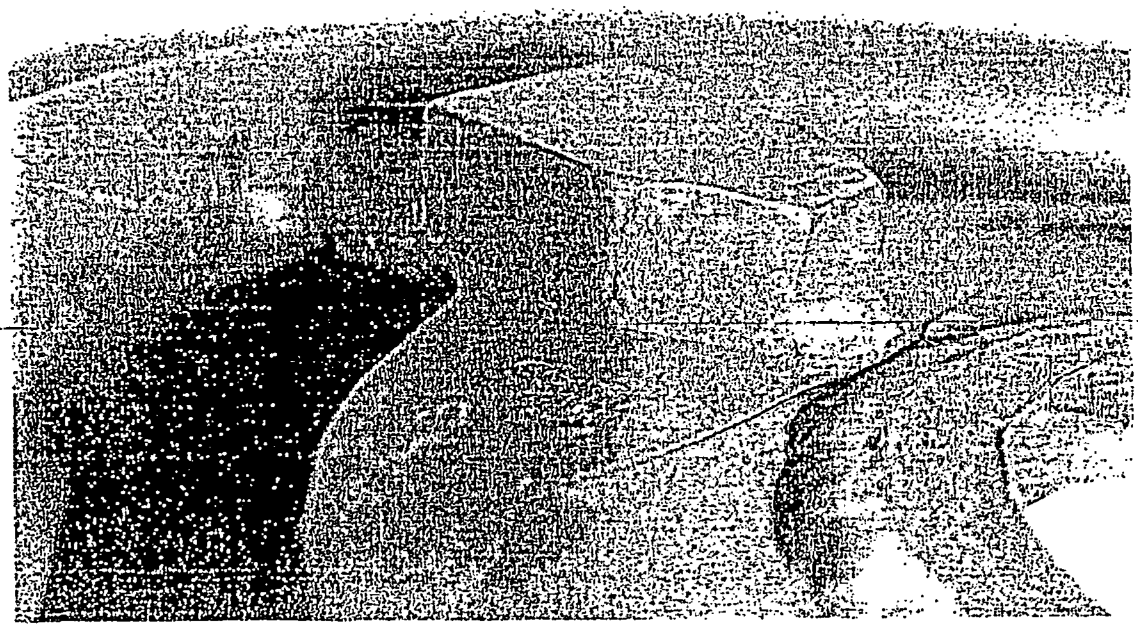


Figure A-2.14. F060B Handwheel and Hub

Figure A-2.15. F060B Handwheel and Hub

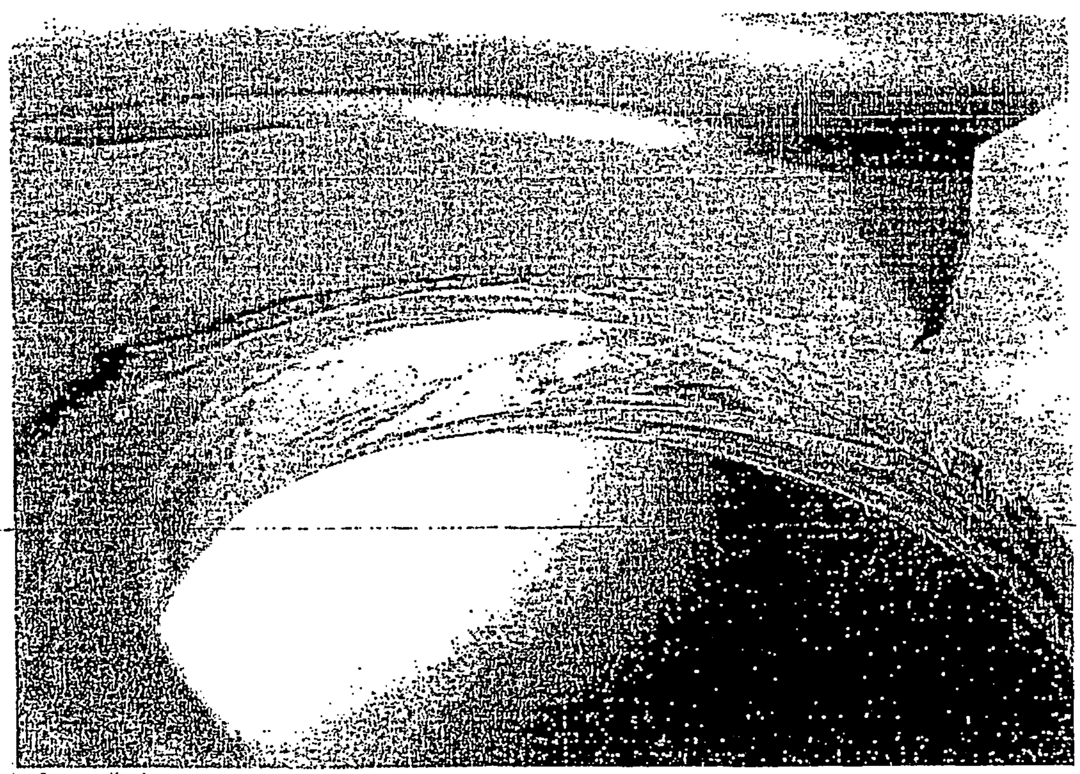


Figure A-2.16. F060B Handwheel and Hub

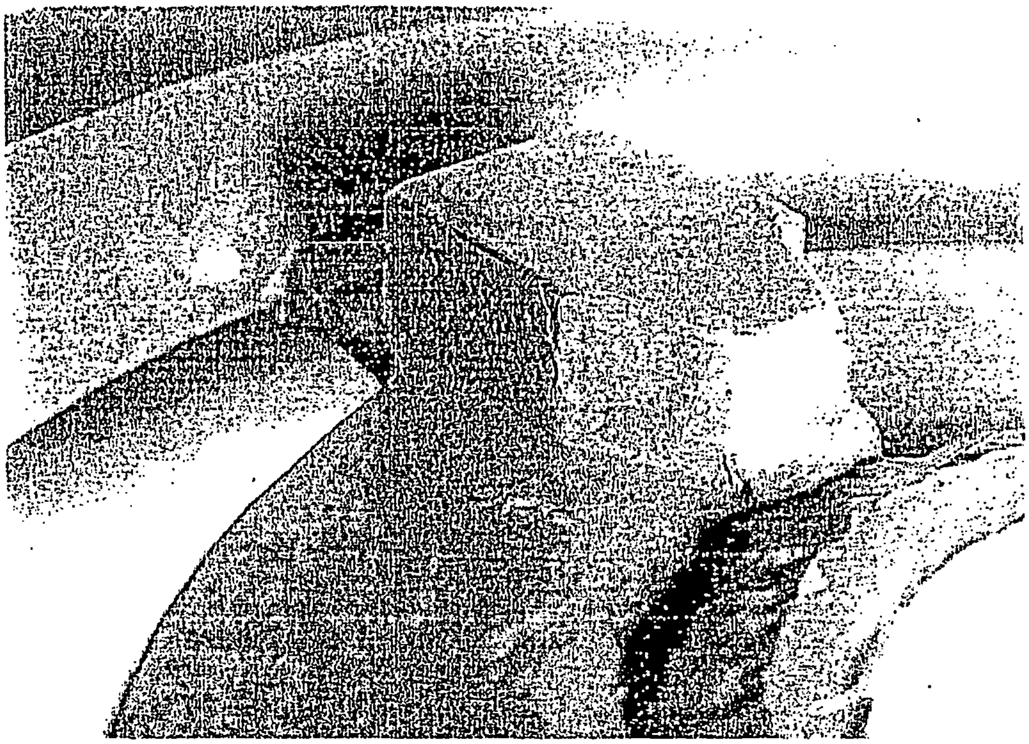


Figure A-2.17. F060B Handwheel and Hub

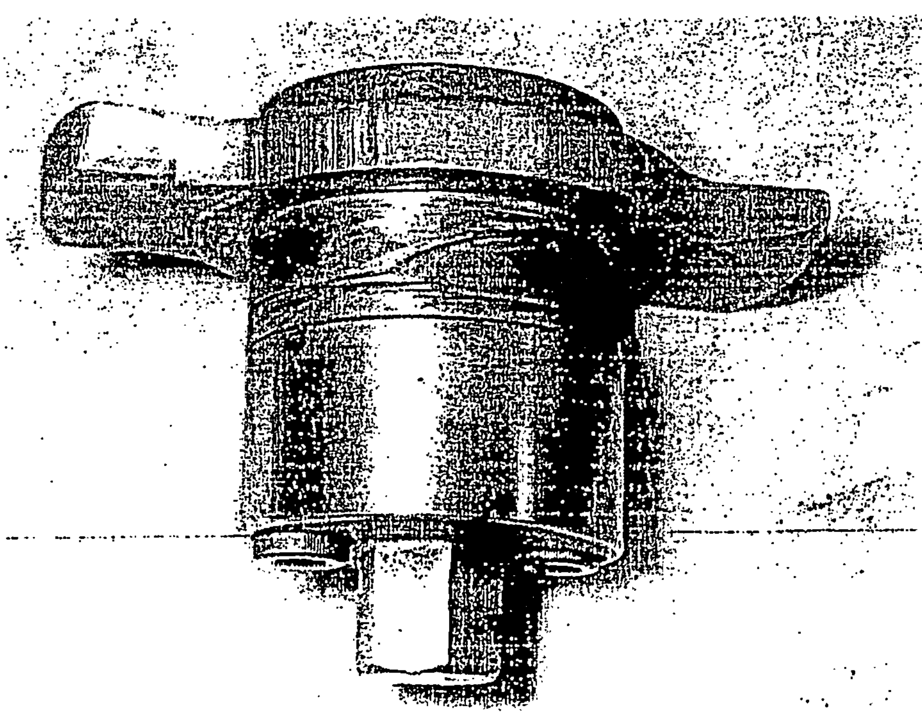


Figure A-2.18. F060B Handwheel and Hub

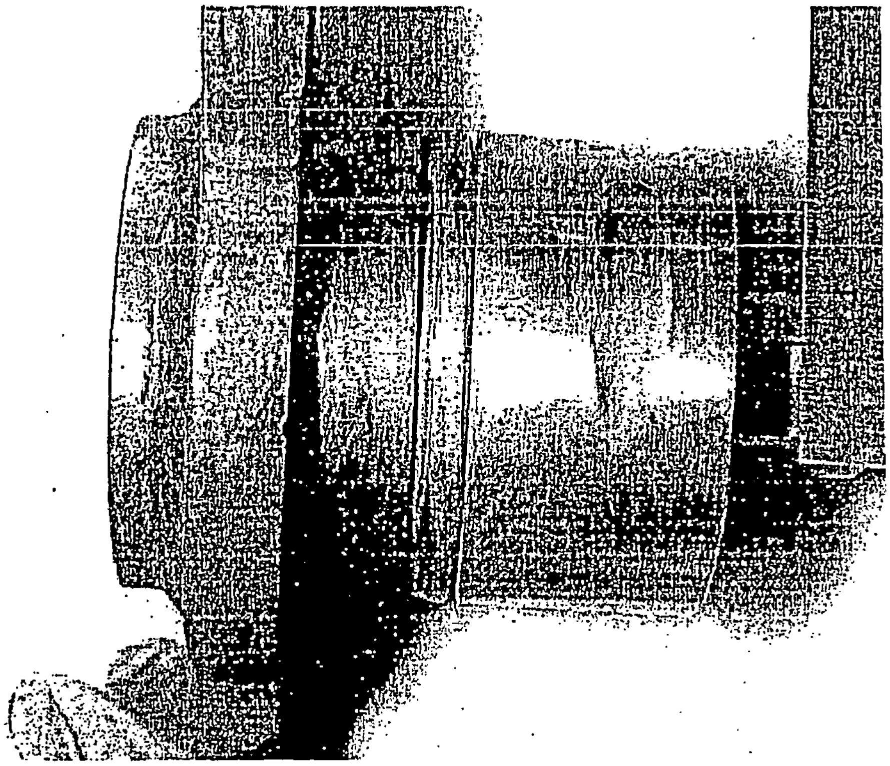


Figure A-2.19. F060B Handwheel and Hub

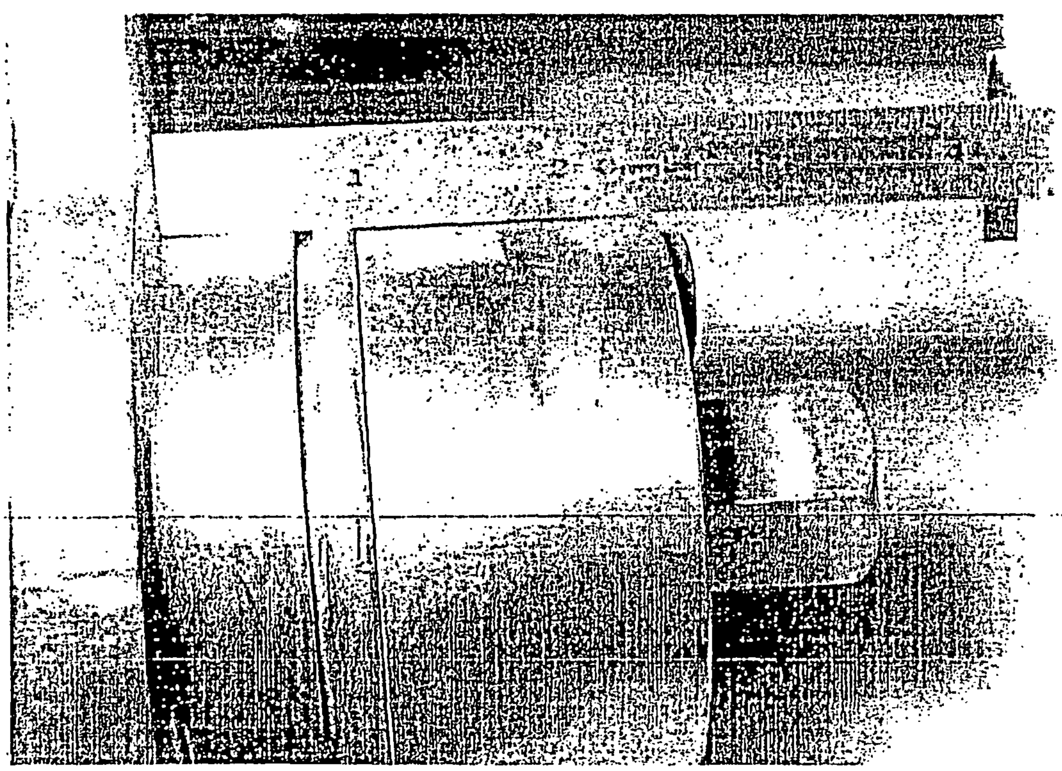


Figure A-2.20. F060B Handwheel and Hub

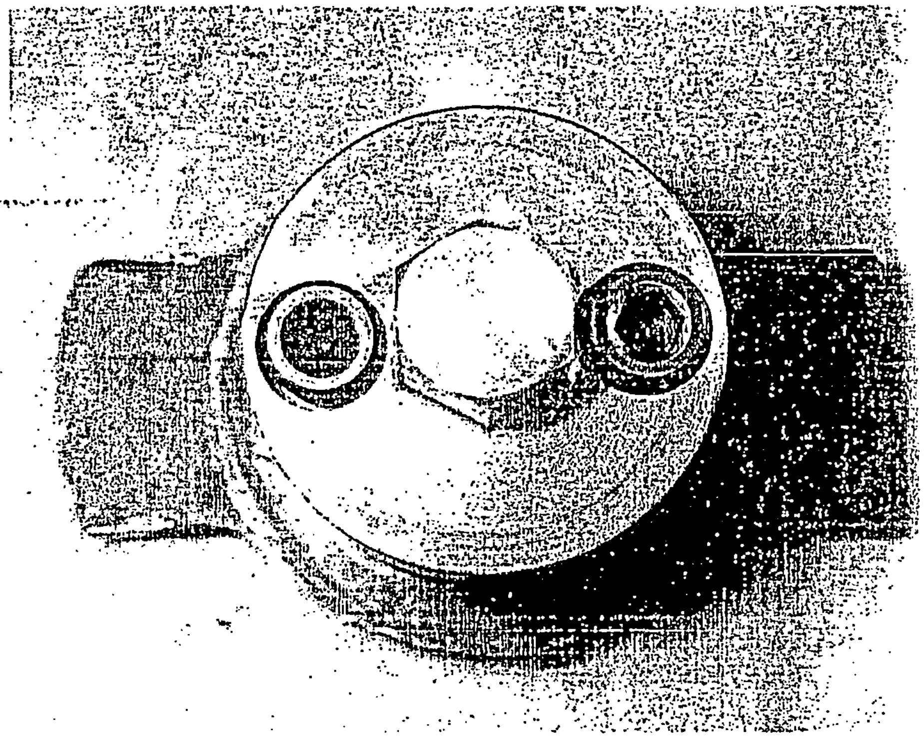


Figure A-2.21. F060B Handwheel and Hub

Figure A-2.22. F060B Handwheel and Hub

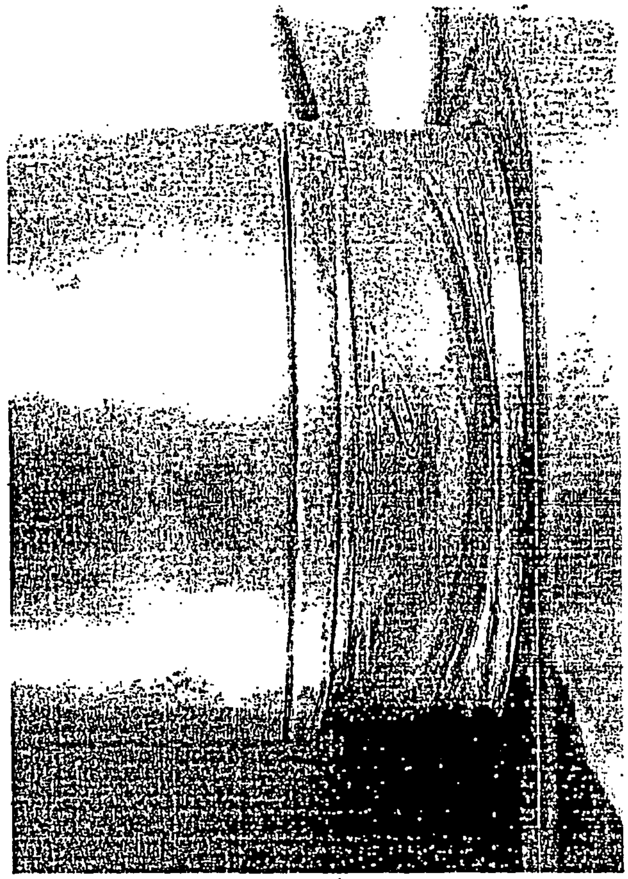


Figure A-2.23. F060B Handwheel and Hub

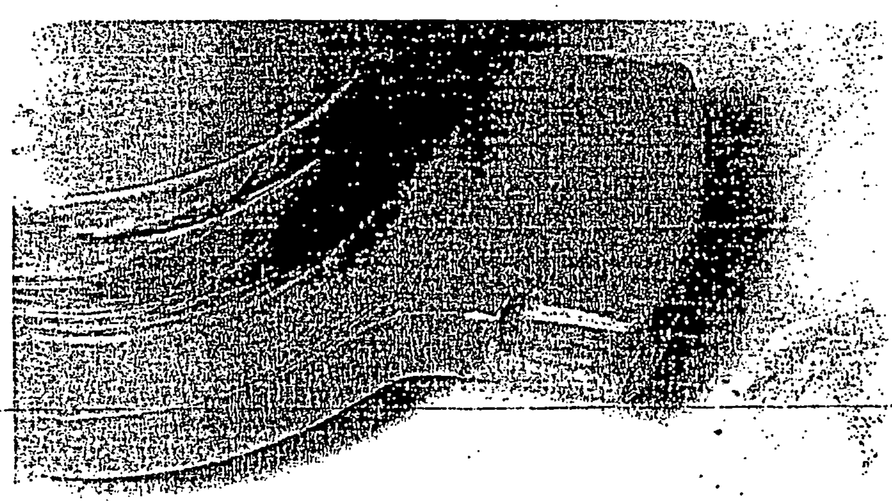


Figure A-2.24. F060B Handwheel and Hub

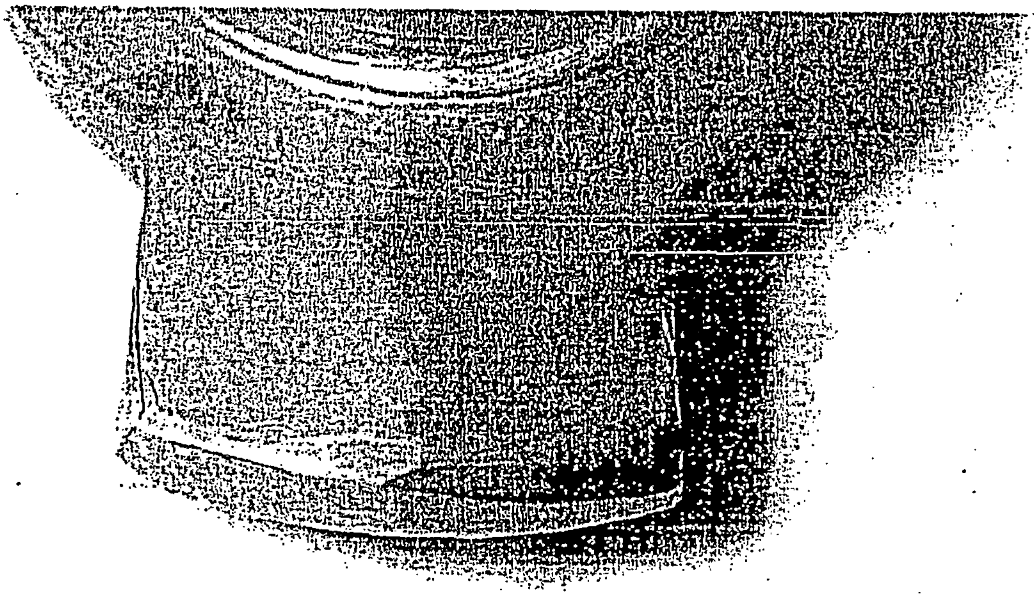


Figure A-2.25. F060B Handwheel and Hub

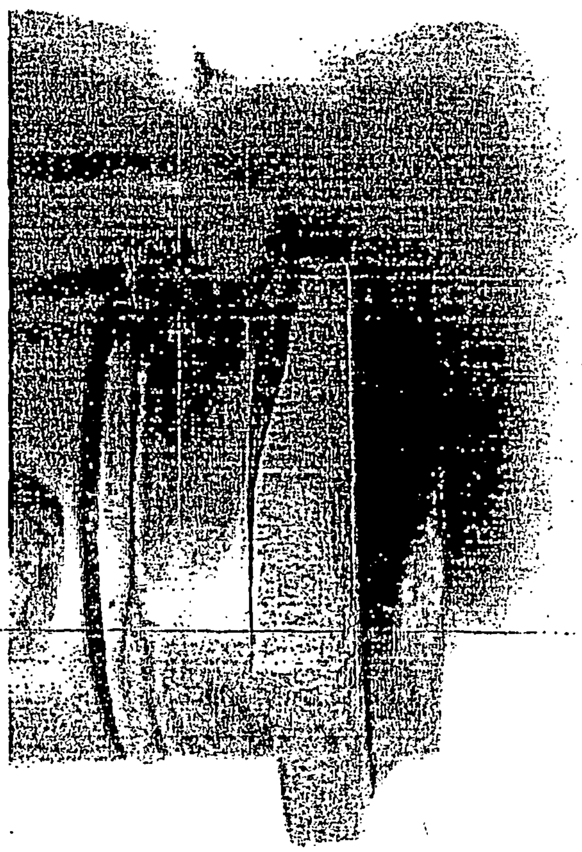


Figure A-2.26. F060B Handwheel and Hub

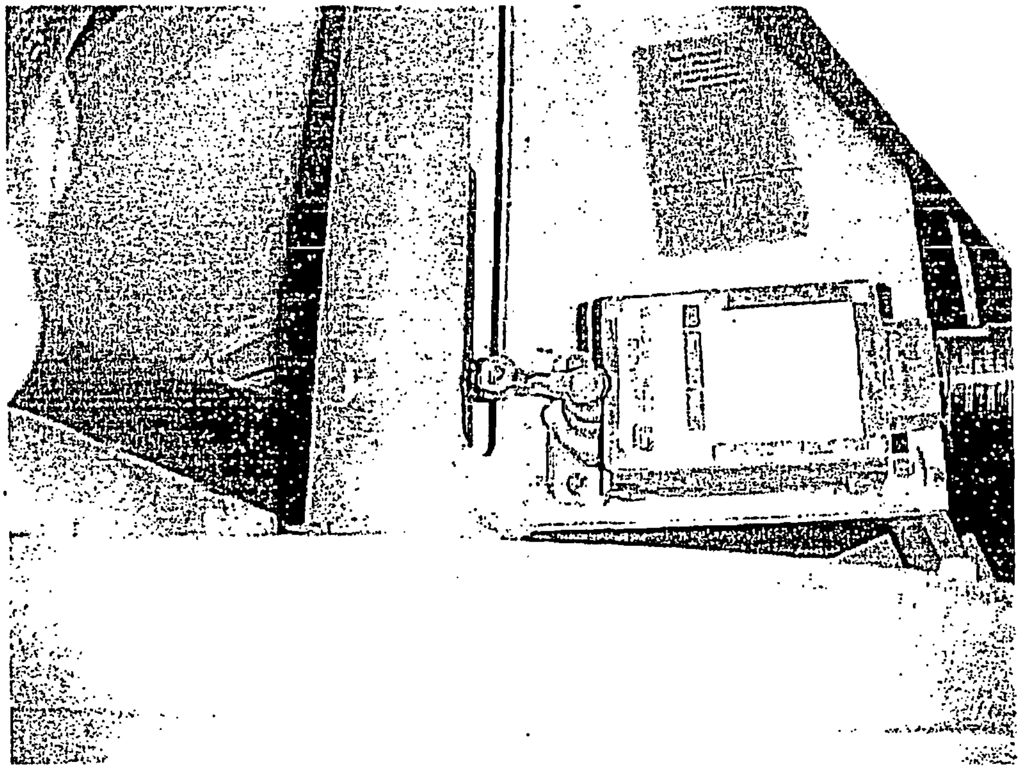


Figure A-3.1. F060A Limit Switch

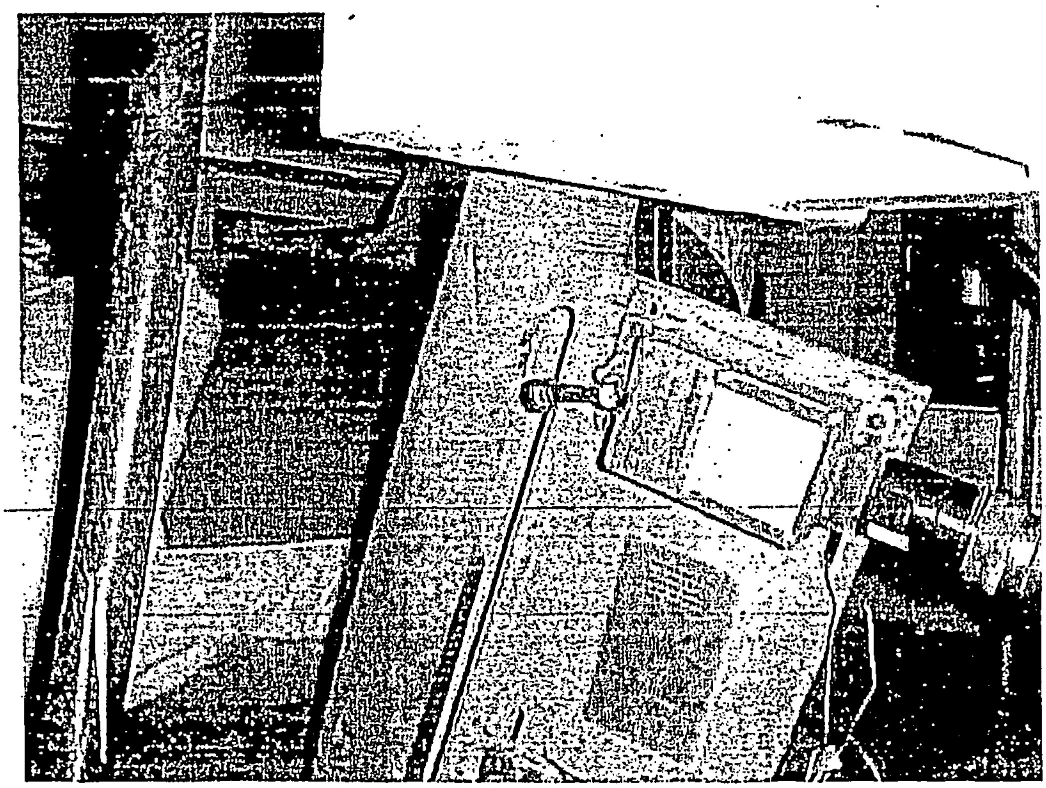


Figure A-3.2. F060A Limit Switch

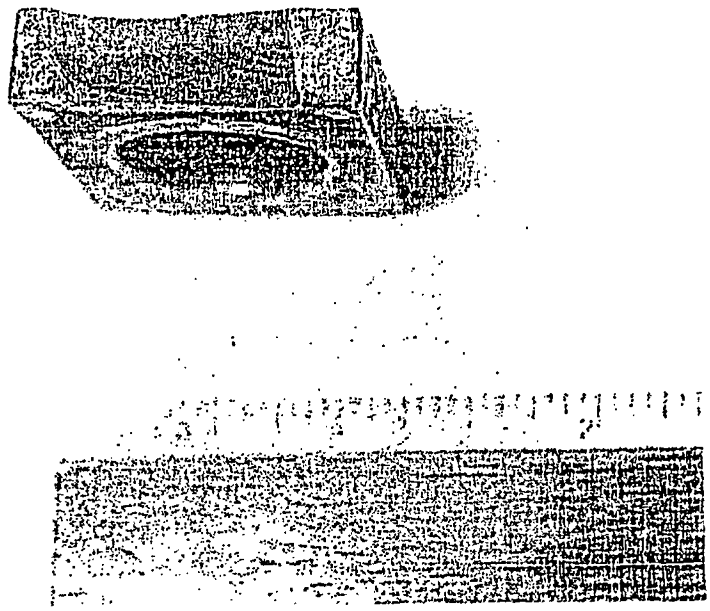


Figure A-3.3. F060A Limit Switch

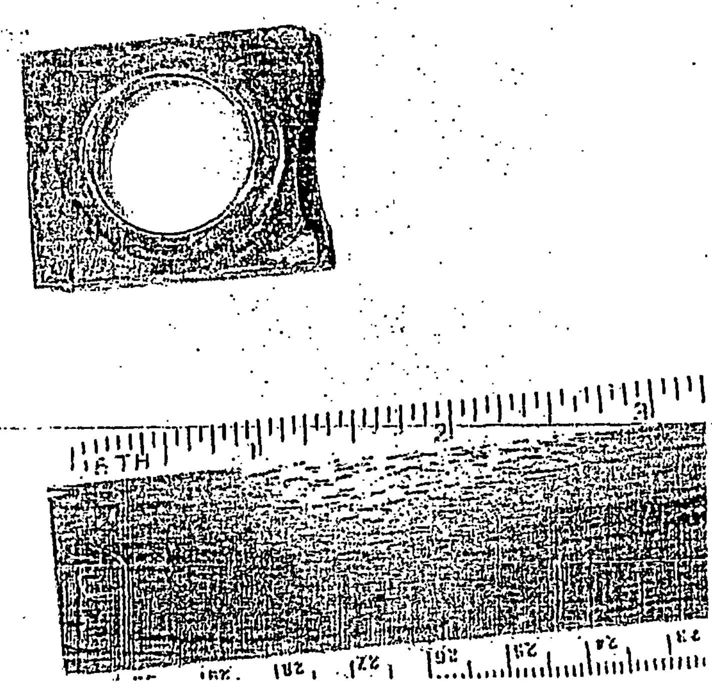


Figure A-3.4. F060A Limit Switch

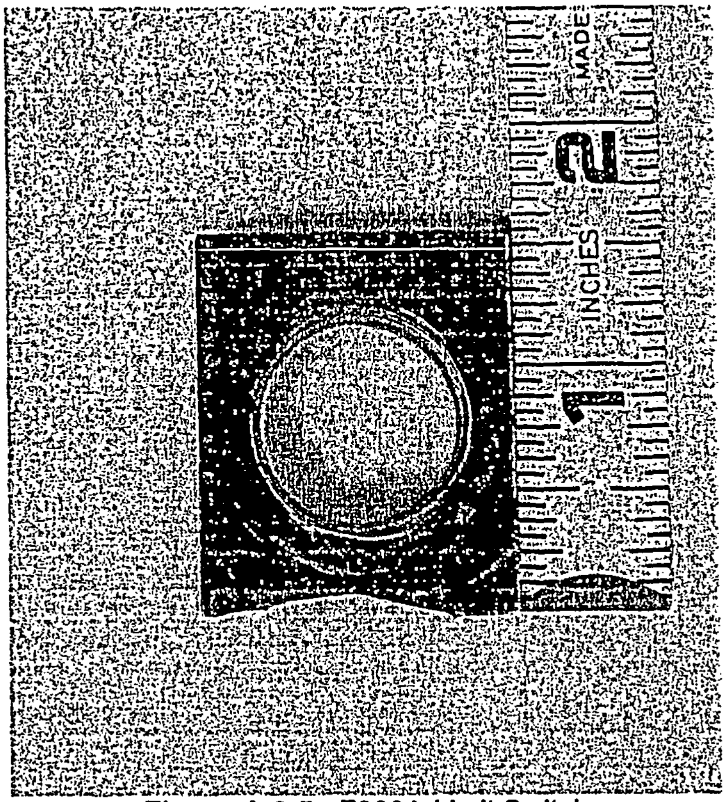


Figure A-3.5. F060A Limit Switch

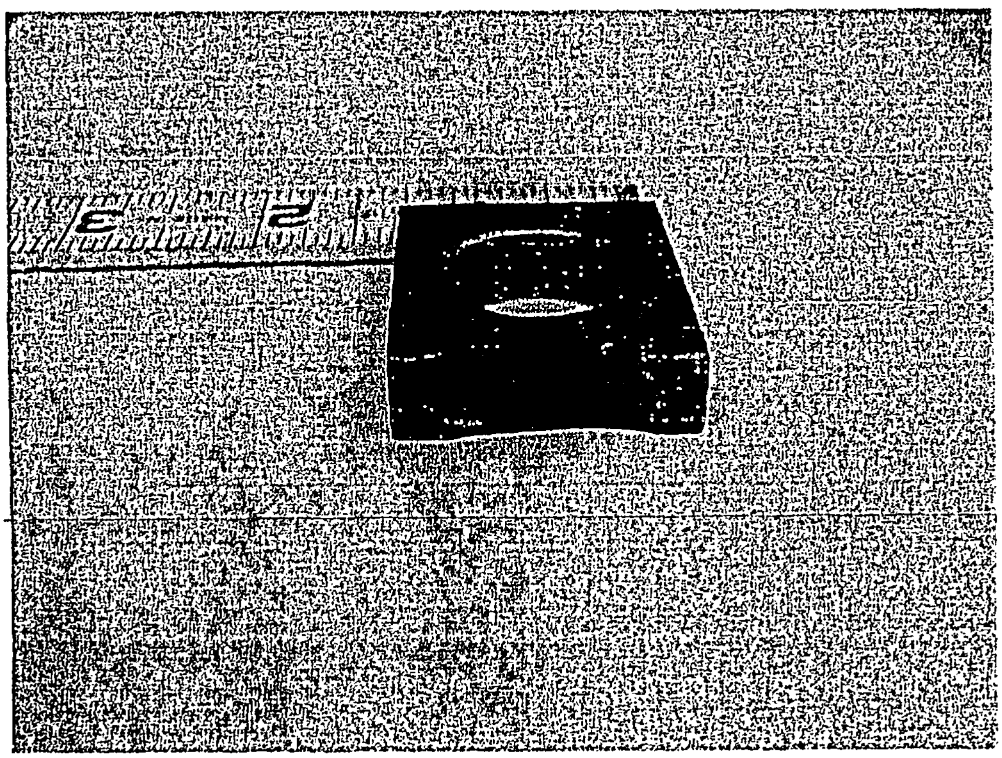


Figure A-3.6. F060A Limit Switch

Figure A-3.7. F060A Limit Switch

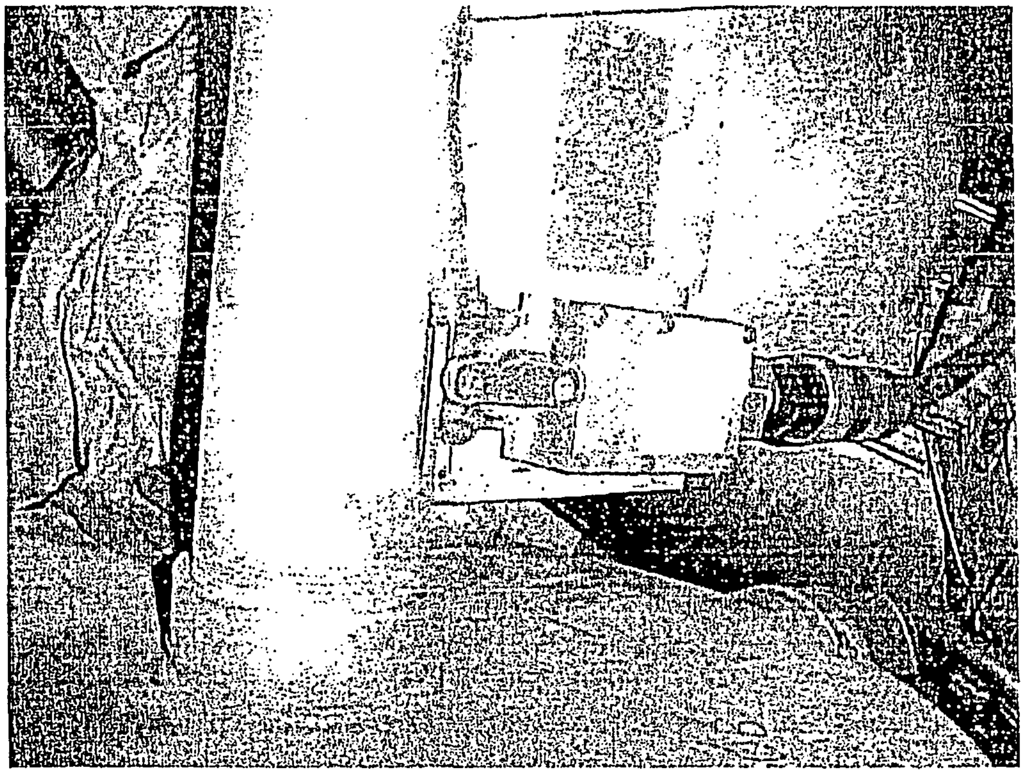


Figure A-4.1. F060B Limit Switch

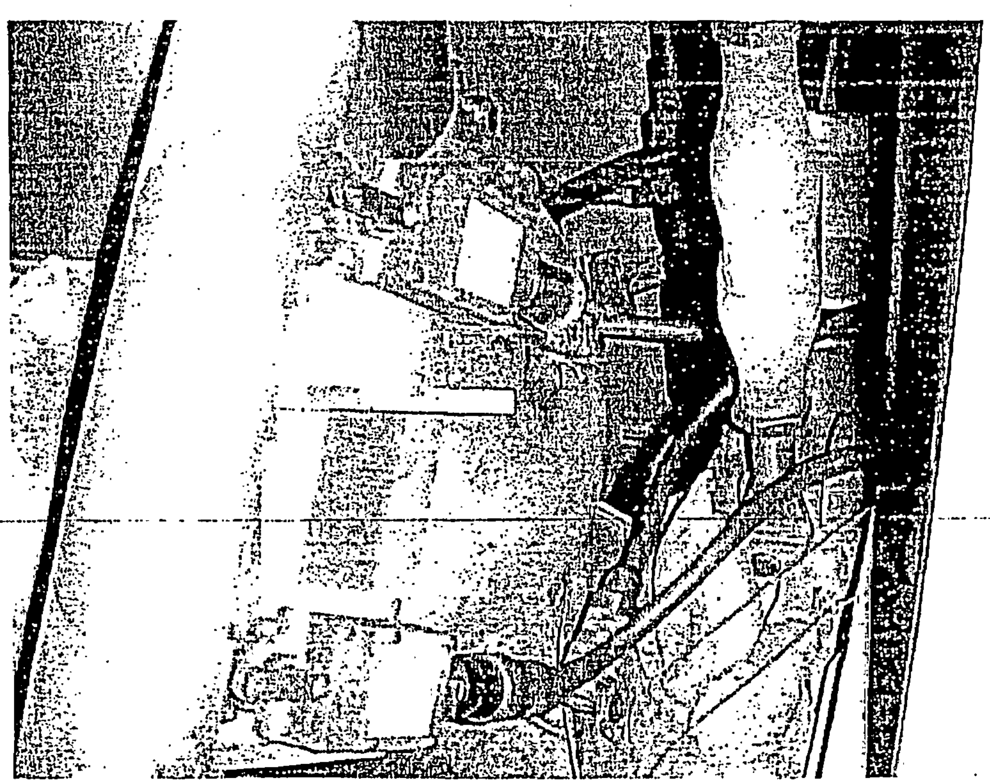


Figure A-4.2. F060B Limit Switch

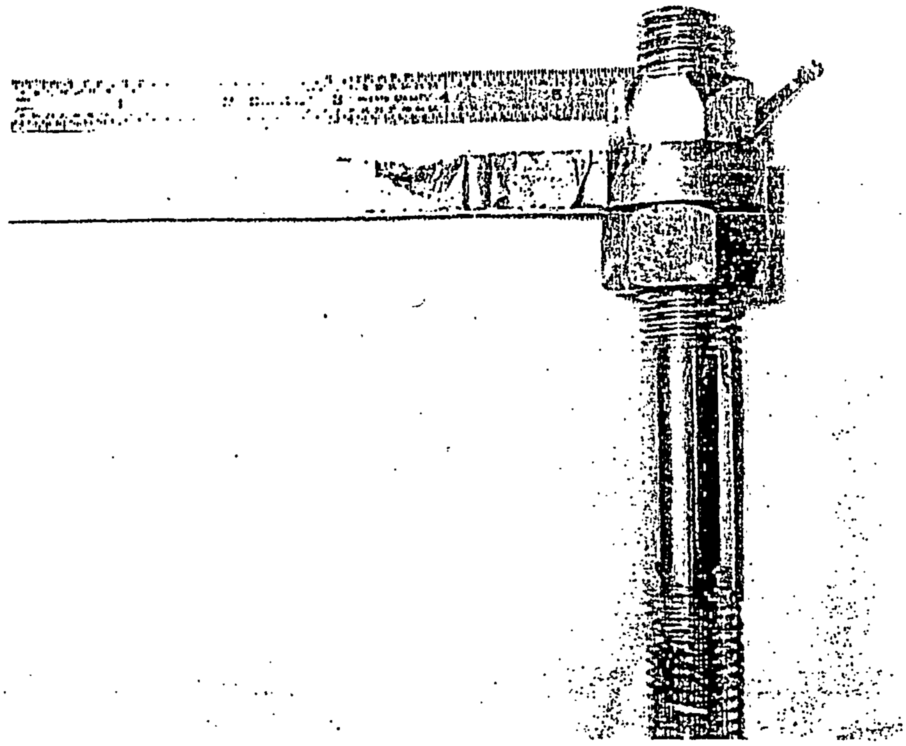


Figure A-4.3. F060B Limit Switch

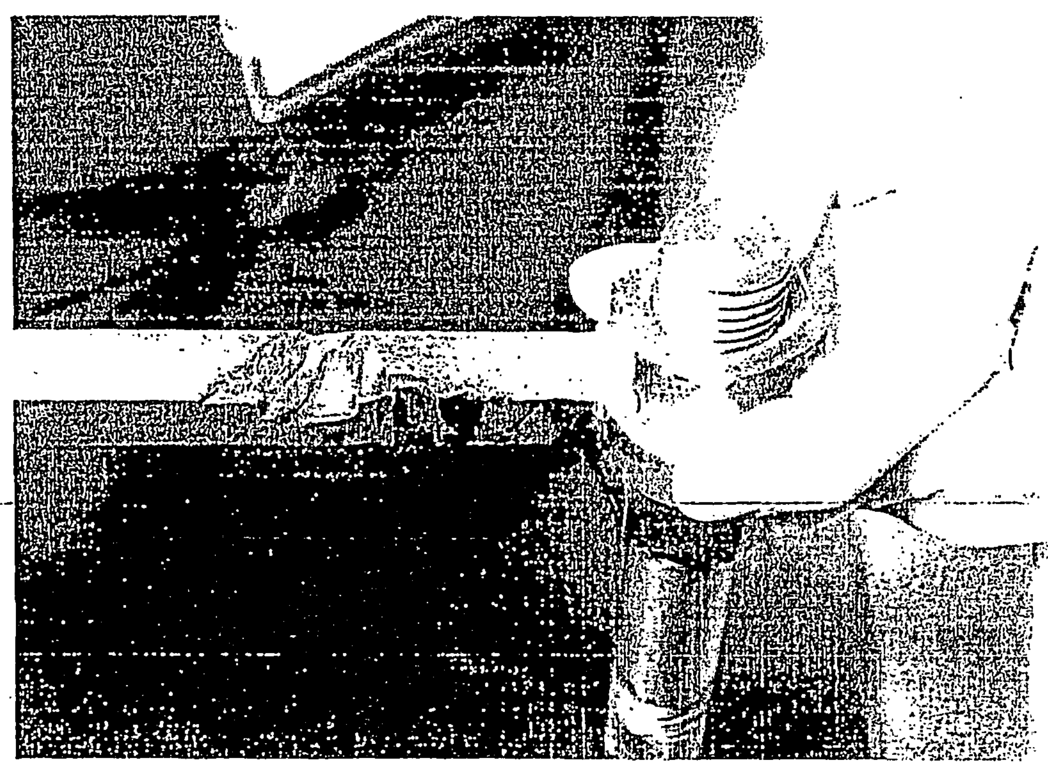


Figure A-4.4. F060B Limit Switch

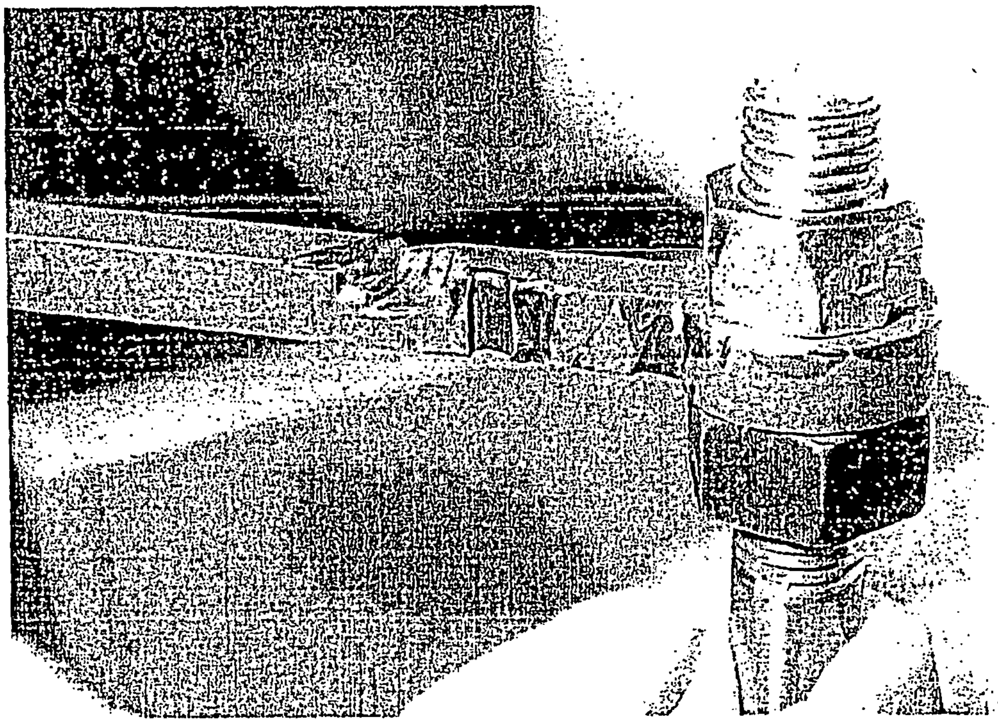


Figure A-4.5. F060B Limit Switch

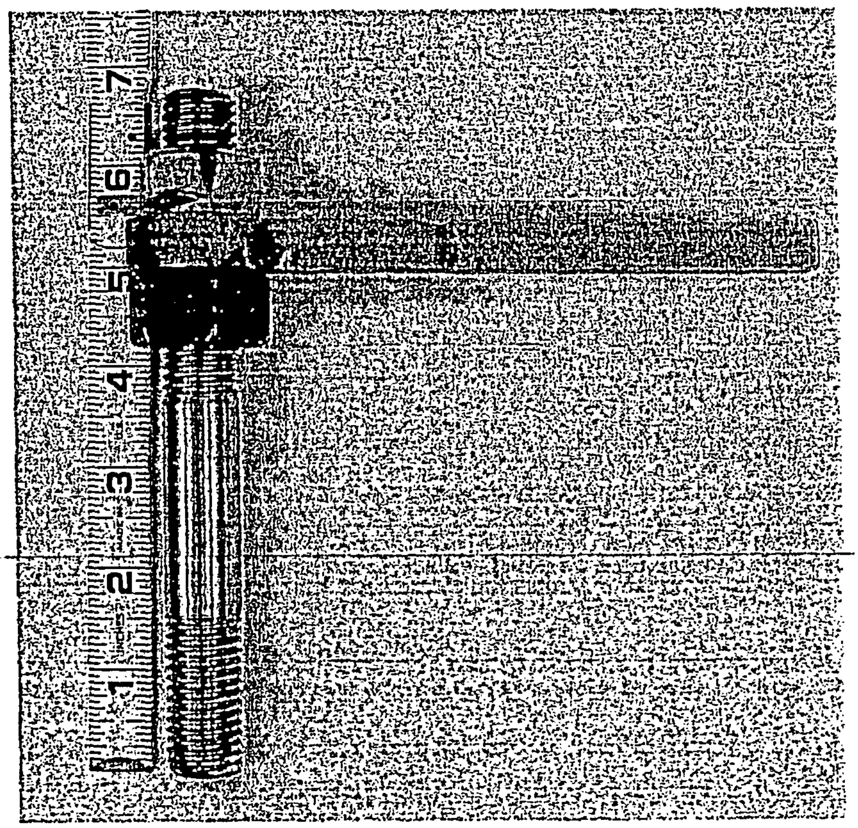


Figure A-4.6. F060B Limit Switch

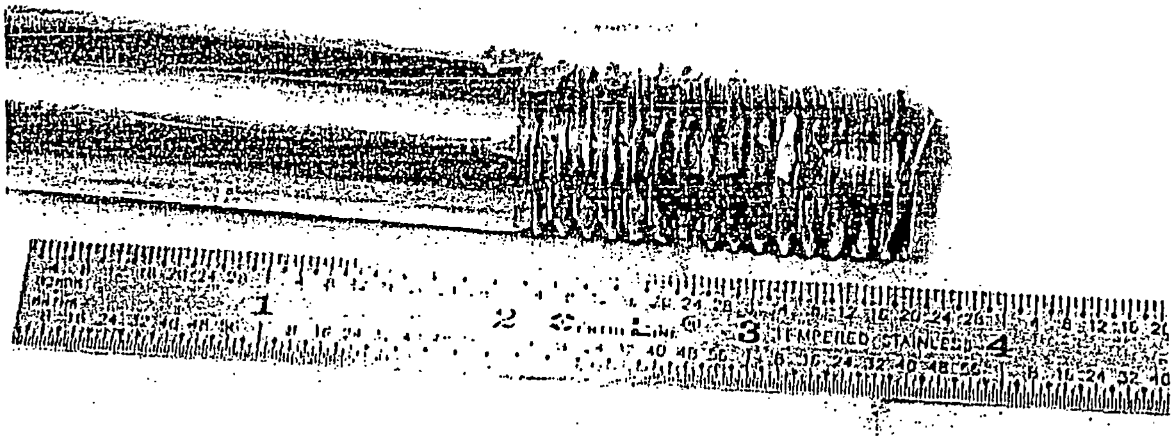


Figure A-4.7. F060B Limit Switch

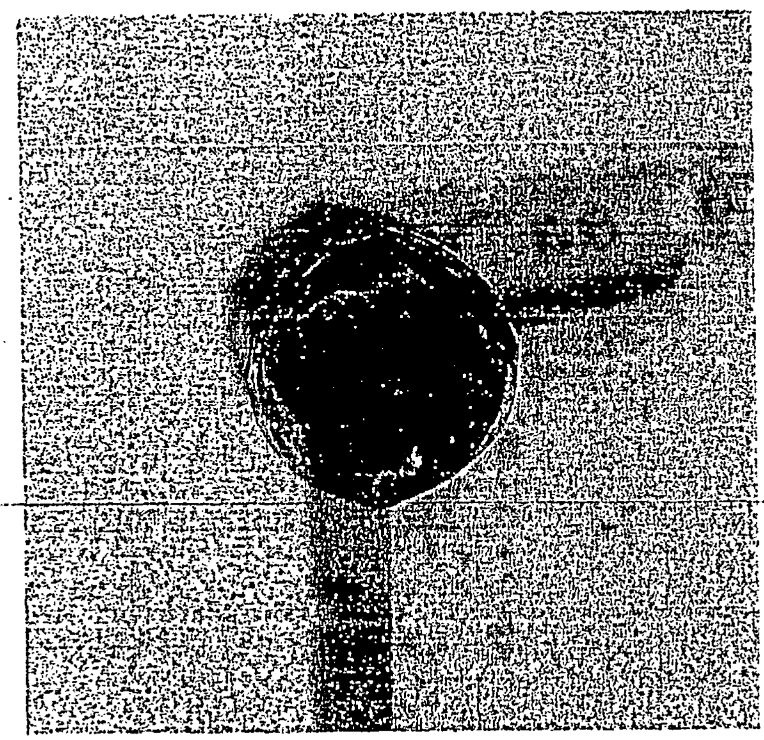


Figure A-4.8. F060B Limit Switch

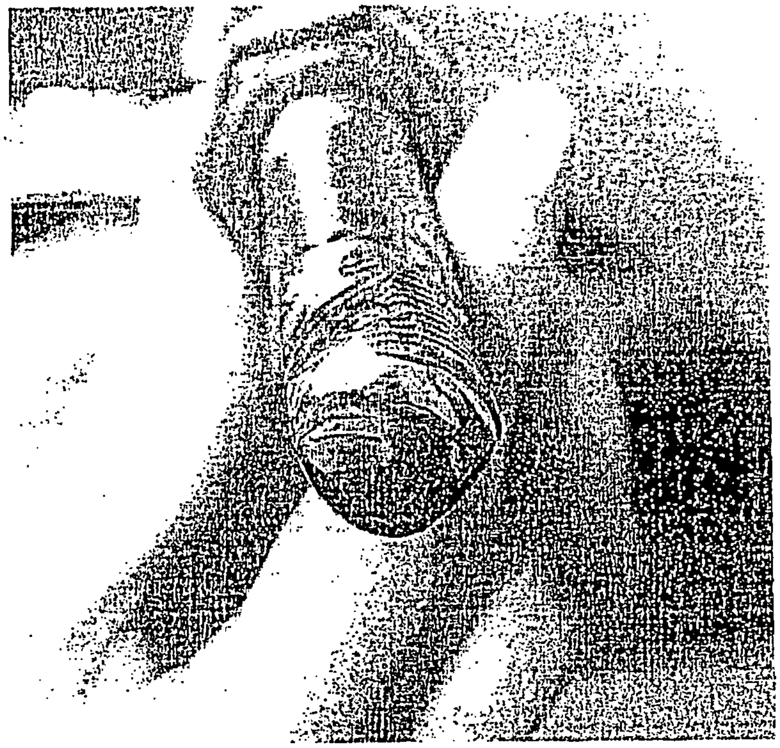


Figure A-4.9. F060B Limit Switch

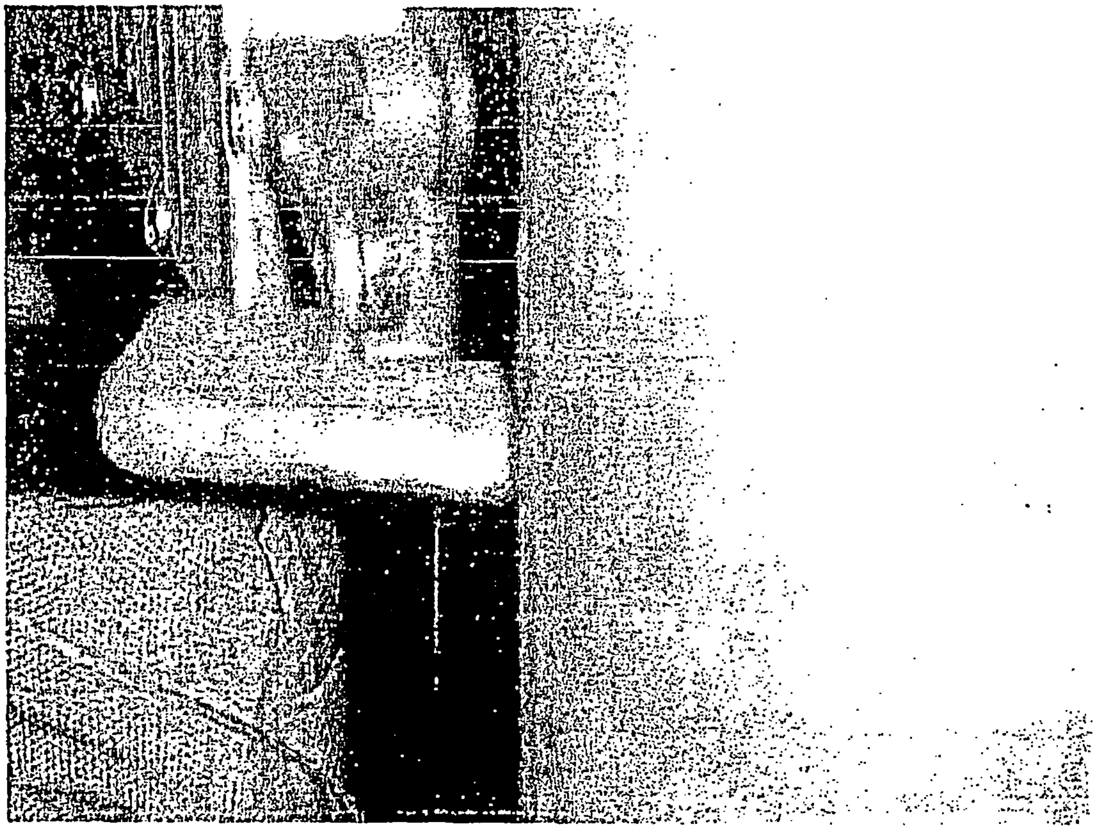


Figure A-5.1. F065D Limit Switch

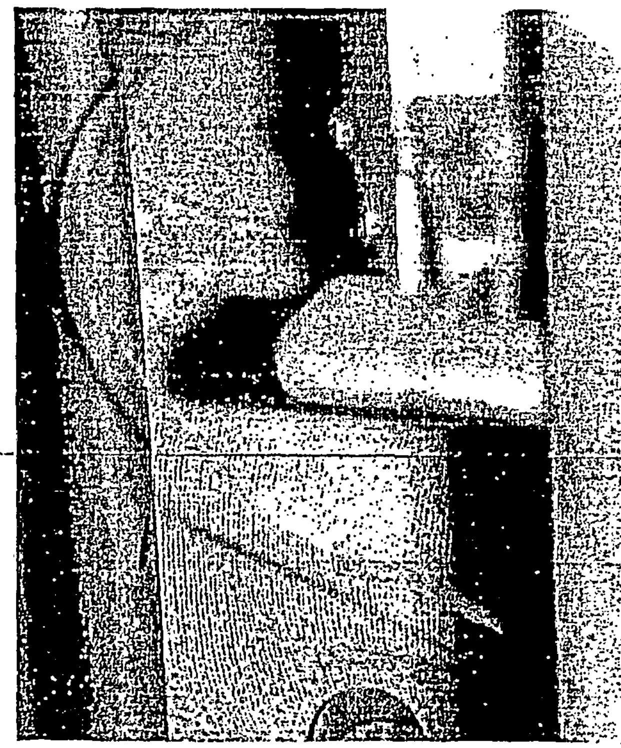


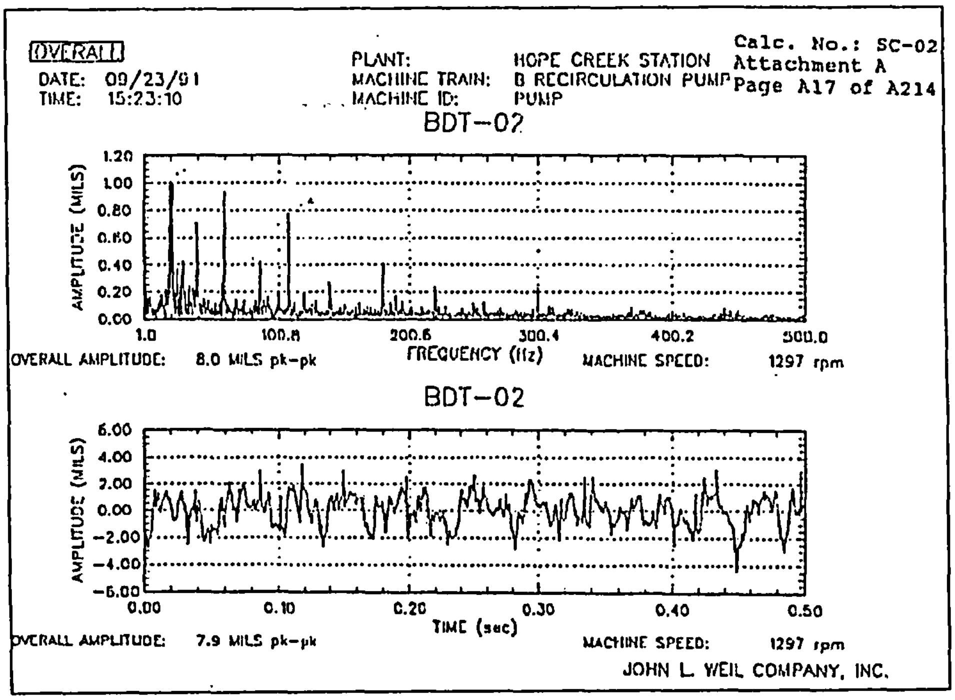
Figure A-5.2. F065D Limit Switch

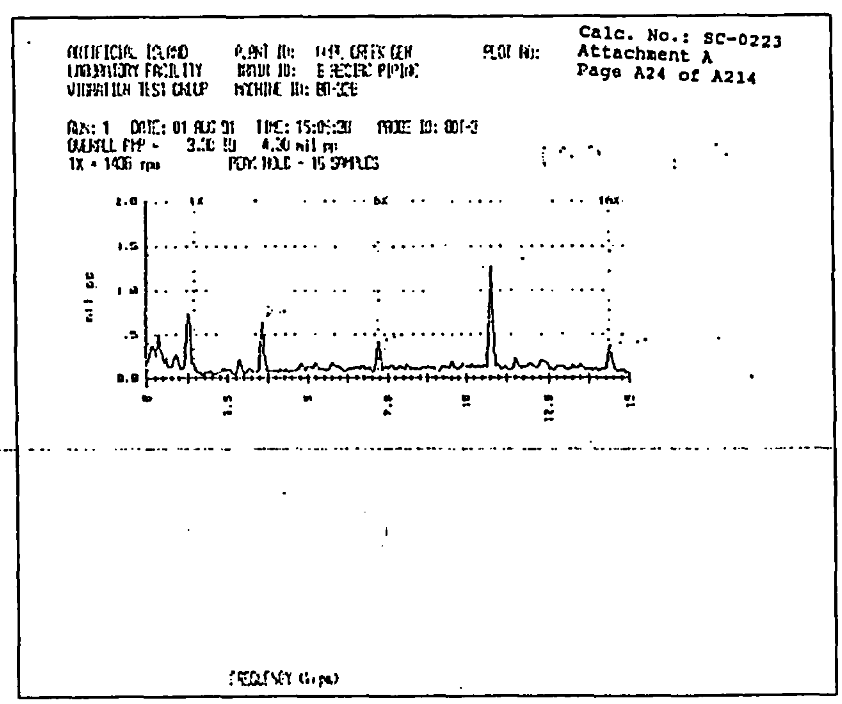
Attachment B: Selected Displacement Results from 1991 Vibration Monitoring of Small Bore Lines

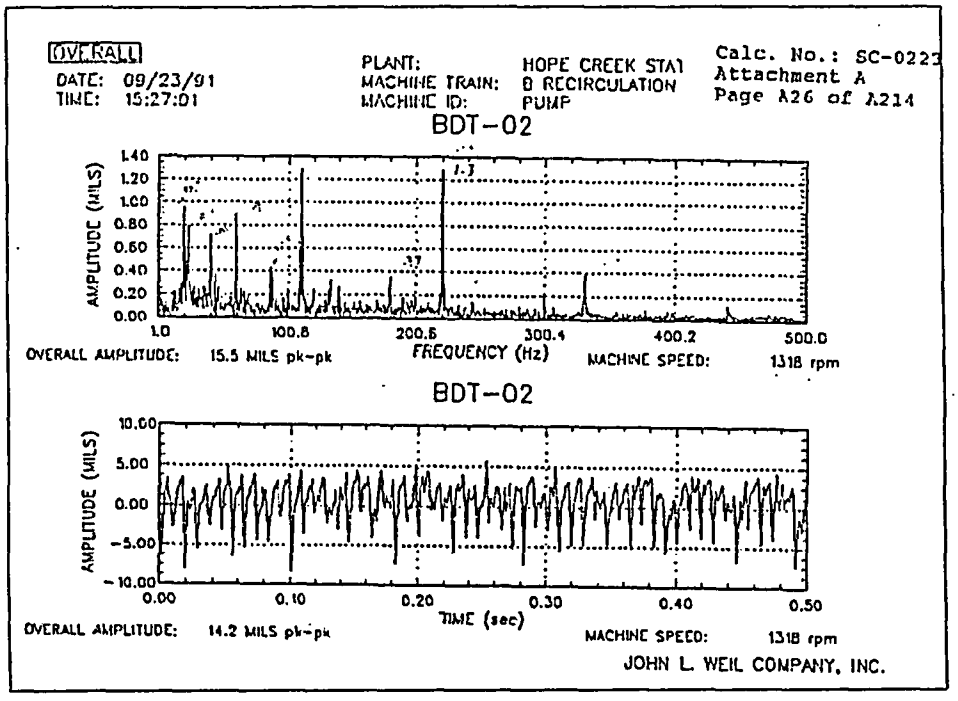
The following plots were obtained from PSEG Nuclear Calculation PSEG Calculation SC-0223, "Evaluation of the Post-Modification Pipe Vibration of the RR Instrumentation Lines," Revision 0. The plots show the displacement versus frequency spectra measured at points on small bore piping lines attached to the Loop A and B recirculation piping on elbows upstream of the recirculation pumps. These plots show that the small bore lines had responses at the recirculation pump running speeds and the vane passing frequencies. This data was collected in 1991.

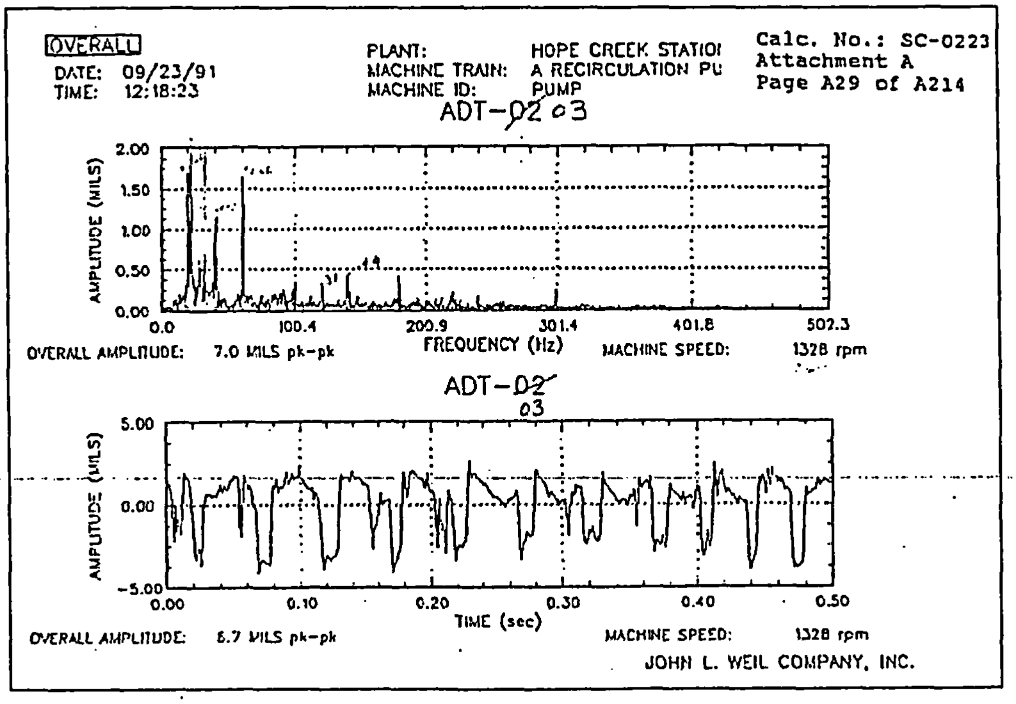
See Table 6-3 in this report for a summary of the data collected during the 1991 testing.

See calculation SC-0223 for more detailed information and for drawings showing the locations where the displacements were measured.


OVERALL
DATE: 09/23/91
TIME: 15:23:10
PLANT: HOPE CREEK STATION
MACHINE TRAIN: B RECIRCULATION PUMP
MACHINE ID: PUMP
Calc. No.: SC-02
Attachment A
Page A17 of A214
BDT-02
AMPLITUDE (MILS)
FREQUENCY (Hz)
OVERALL AMPLITUDE: 8.0 MILS pk-pk
MACHINE SPEED: 1297 rpm
BDT-02
AMPLITUDE (MILS)
TIME (sec)
OVERALL AMPLITUDE: 7.9 MILS pk-pk
MACHINE SPEED: 1297 rpm
JOHN L. WEIL COMPANY, INC.


Calc. No.: SC-0223
Attachment A
Page A24 of A214


OVERALL
DATE: 09/23/91
TIME: 15:27:01
PLANT: HOPE CREEK STA
MACHINE TRAIN: B RECIRCULATION
MACHINE ID: PUMP
Calc. No.: SC-0223
Attachment A
Page A26 of A214
BDT-02
AMPLITUDE (MILS)
FREQUENCY (Hz)
OVERALL AMPLITUDE: 15.5 MILS pk-pk
MACHINE SPEED: 1318 rpm
BDT-02
TIME (sec)
OVERALL AMPLITUDE: 14.2 MILS pk-pk
MACHINE SPEED: 1318 rpm
JOHN L. WEIL COMPANY, INC.

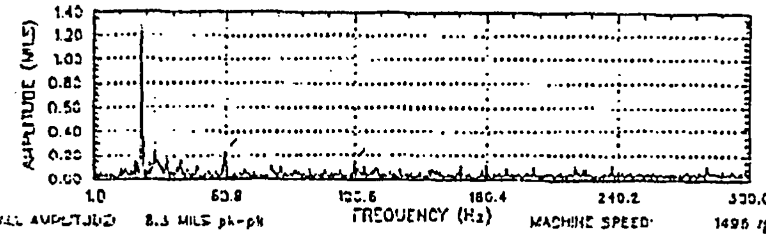

OVERALL
DATE: 09/23/91
TIME: 12:18:23
PLANT: HOPE CREEK STATIO
MACHINE TRAIN: A RECIRCULATION PU
MACHINE ID: PUMP
Calc. No.: SC-0223
Attachment A
Page A29 of A214
ADT-02 03
AMPLITUDE (MILS)
FREQUENCY (Hz)
OVERALL AMPLITUDE: 7.0 MILS pk-pk
MACHINE SPEED: 1328 rpm
ADT-02 03
TIME (sec)
OVERALL AMPLITUDE: 6.7 MILS pk-pk
MACHINE SPEED: 1328 rpm
JOHN L. WEIL COMPANY, INC.

OVERALL
DATE: 09/23/91
TIME: 13:42:45

PLANT: HOPE CREEK STATION
MACHINE TRAIN: A RECIRCULATION PUMP
MACHINE ID: PUMP

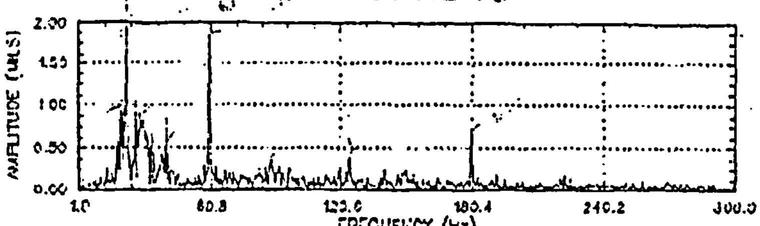
Calc. No.: SC-0223
Attachment A
Page A30 of A214

ADT-C1



OVERALL AMPLITUDE: 8.3 MILS pk-pk MACHINE SPEED: 1496 rpm

ADT-02



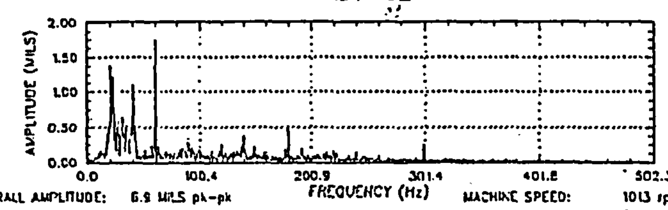
OVERALL AMPLITUDE: 7.2 MILS pk-pk MACHINE SPEED: 1496 rpm

JOHN L. WEIL COMPANY, INC.

OVERALL
DATE: 09/23/91
TIME: 10:46:03

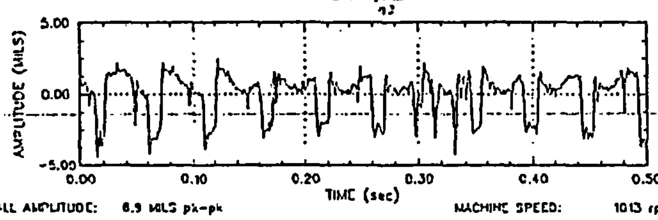
PLANT: HOPE CREEK STATION
MACHINE TRAIN: A RECIRCULATION PUMP
MACHINE ID: PUMP

ADT-02



OVERALL AMPLITUDE: 6.9 MILS pk-pk MACHINE SPEED: 1013 rpm

ADT-02



OVERALL AMPLITUDE: 6.9 MILS pk-pk MACHINE SPEED: 1013 rpm

JOHN L. WEIL COMPANY, INC.

LVDT, STRAIN GAGE AND ACCELEROMETER DATA (Loop A

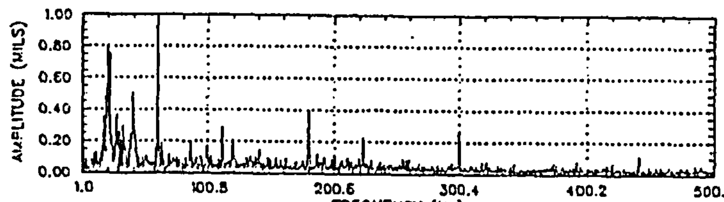
Calc. No.: SC-0223
Attachment A
Page A42 of A214

OVERALL
DATE: 09/23/91
TIME: 15:26:50

PLANT: HOPE CREEK STATION
MACHINE TRAIN: B RECIRCULATION PUMP
MACHINE ID: PUMP

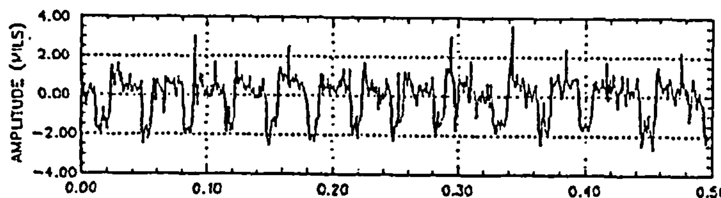
Calc. No.: SC-0223
Attachment A
Page A114 of A214

BDT-02



OVERALL AMPLITUDE: 6.6 MILS pk-pk MACHINE SPEED: 1339 rpm

BDT-02



OVERALL AMPLITUDE: 6.4 MILS pk-pk MACHINE SPEED: 1339 rpm

JOHN L. WEIL COMPANY, INC.

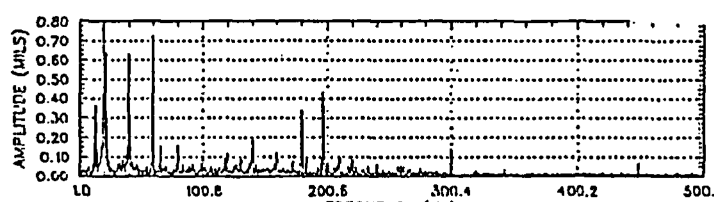
LVDT, STRAIN GAGE AND ACCELEROMETER DATA FOR LOOP B

OVERALL
DATE: 09/23/91
TIME: 13:08:52

PLANT: HOPE CREEK STATION
MACHINE TRAIN: B RECIRCULATION PUMP
MACHINE ID: PUMP

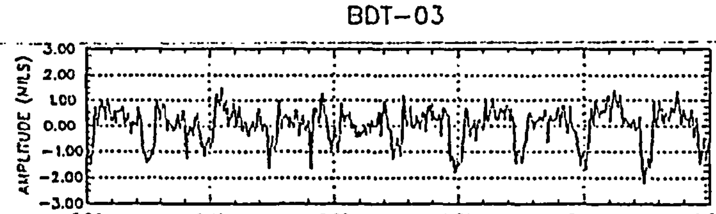
Calc. No.: SC-0223
Attachment A
Page A118 of A214

BDT-03



OVERALL AMPLITUDE: 4.1 MILS pk-pk MACHINE SPEED: 784 rpm

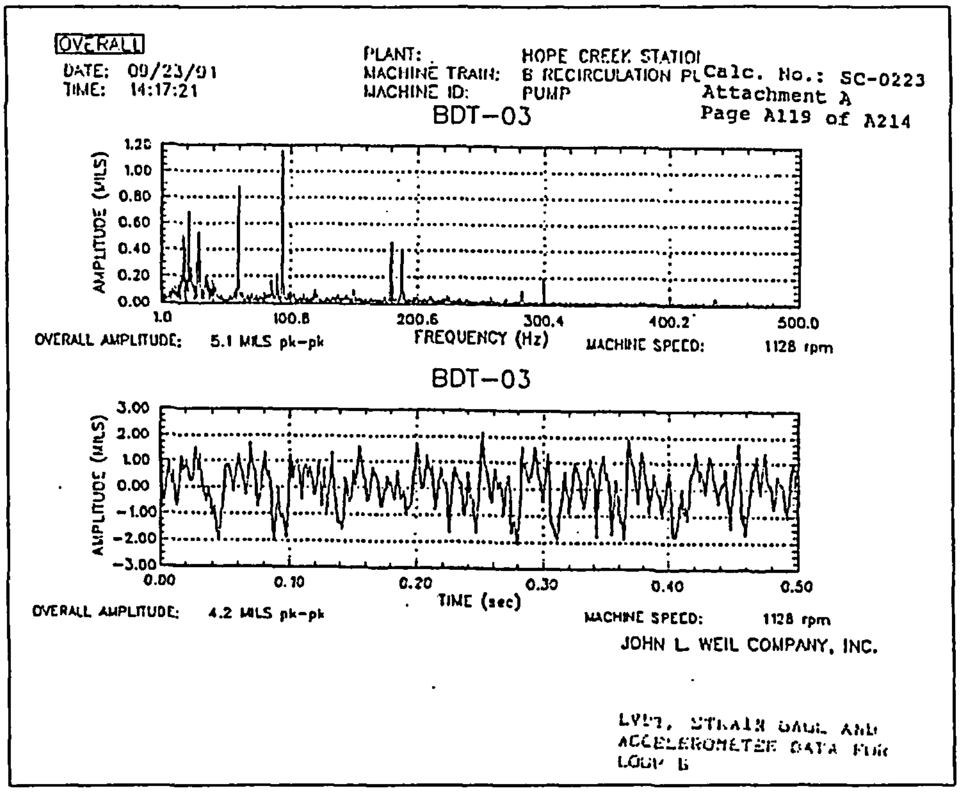
BDT-03



OVERALL AMPLITUDE: 3.8 MILS pk-pk MACHINE SPEED: 784 rpm

JOHN L. WEIL COMPANY, INC.

LVDT, STRAIN GAGE AND ACCELEROMETER DATA FOR LOOP B


OVERALL
DATE: 09/23/91
TIME: 14:17:21
PLANT: HOPE CREEK STATIOI
MACHINE TRAIN: B RECIRCULATION PL
MACHINE ID: PUMP
Calc. No.: SC-0223
Attachment A
Page A119 of A214
BDT-03
AMPLITUDE (MILS)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.0
100.8
200.6
300.4
400.2
500.0
FREQUENCY (Hz)
OVERALL AMPLITUDE: 5.1 MILS pk-pk
MACHINE SPEED: 1128 rpm
BDT-03
AMPLITUDE (MILS)
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
0.00
0.10
0.20
0.30
0.40
0.50
TIME (sec)
OVERALL AMPLITUDE: 4.2 MILS pk-pk
MACHINE SPEED: 1128 rpm
JOHN L. WEIL COMPANY, INC.

Attachment C: Investigation of Possible Acoustic Natural Frequencies in the Recirculation and RHR Piping

As stated in the body of this evaluation, the maximum acceleration responses recorded by the accelerometers installed in the drywell generally occurred at the pump vane passing frequency. The acceleration response at the vane passing frequency is plotted against the vane passing frequency in Figure 6-2. These plots are based on data recorded as the pump speeds increased with plant power over several weeks and therefore represent a range of vane passing frequencies from about 37.5 to 125 Hz.

Based on the plots contained in Figure 6-2, several observations can be made. First, accelerations observed at vane passing frequencies below 80 Hz (equivalent to pump running speed of 960 rpm) are relatively small. Above 80 Hz the plots show a consistent pattern of high acceleration responses at three frequencies. The acceleration responses have peaks at vane passing frequencies centered around 90 Hz and 108 Hz and 125 Hz (equivalent to pump running speed of 1080, 1296, and 1500 rpm, respectively).

Similar behavior was observed in all 12 working accelerometers. Since these accelerometers are in varying locations and orientations throughout the piping system, it is unlikely that these peak responses occurring at the same discrete frequencies (roughly 90 Hz, 108 Hz and 125 Hz) can all be attributed to structural resonances. That is, since the accelerometers were placed at different locations on the piping and in different orientations it is unlikely that size, geometry, and support arrangement of the piping would be such that all 12 locations would have the same structural natural frequencies at these discrete values.

However, the resonant response observed in the plots may instead result from acoustic resonance of the piping system. This effect is analogous to the fundamental frequency produced by a closed organ pipe. The recirculation system pump's vane passing frequency provides the driving frequency to the piping system. When the pump vane passing speeds hit odd multiples of the fundamental frequency of the piping system, an acoustic resonance may be created which would increase vibration in the system. The possibility of acoustic resonance in the piping system including the frequencies and system characteristics necessary to produce acoustic resonance is explored in this attachment.

Approach

The equation for the fundamental frequency for a closed pipe is given by Equation C-1 (Reference C-1)..

$$f_1 = \frac{v}{4 * L} \qquad \text{Equation C-1}$$

Where:

f_1 = Fundamental frequency of the system
v = Speed of sound
L = Pipe length

The normal-mode frequencies occur only at the odd multiples of this fundamental frequency (1, 3, 5...) and no resonance occurs at the even multiples of the fundamental frequency (2, 4, 6...). The Hope Creek peak accelerations occur at vane passing frequencies of about 90 Hz, 108 Hz and 125 Hz, over the range measured. The even spacing between these peaks, at 17-18 Hz, may indicate that there is a fundamental natural frequency equal to half of that band, at or about 8.5 Hz. Further exploration shows that if the system has a fundamental natural frequency of 8.3 Hz, then the 11th, 13th, and 15th harmonics would fall at 91.3, 107.9, and 124.5 Hz, respectively, approximating the results observed in Figure 6-2.

Assuming there is a fundamental frequency of 8.3 Hz in the system, the corresponding pipe length can be determining using Equation C-1 as shown below.

$$L = \frac{v}{4 * f_1}$$ Equation C-2

To solve for the corresponding pipe length the speed of sound in water at the recirculation system operating conditions is required. The speed of sound in water is listed in the ASME Steam Tables (Reference C-2) at specific pressure and temperature conditions. At the Hope Creek recirc system conditions when vibration data was taken (specifically, 939 psig and 532°F), the speed of sound from the ASME steam tables can be approximated as 3445 ft/sec. (This is the value at 1000 psia and 525°F, the conditions most nearly applicable listed in the steam tables.)

For this speed of sound and the 8.3 Hz fundamental frequency, the corresponding pipe length is calculated using about 104 feet. Review of the recirculation system Loop A and B isometric drawings shows that the length of 28" diameter pipe from the reactor vessel suction nozzle to the cross connection where the 28" diameter discharge pipe connects to the 22" feed header to the five jet pumps is about 111 feet. This represents the distance between the two points where the pipe flow area changes; such points can act as acoustic boundaries.

This is within about seven percent of the acoustic length calculated above. This is considered to be a close result due to uncertainty in the speed of sound. This result suggests that the recirculation system acoustics may be such that the pump vane passing frequency pressure fluctuations are exciting harmonics of the system fundamental acoustical natural frequency, leading to amplified pressure pulsation response at specific vane passing frequencies.

It is possible that there are other acoustic modes of the system, involving the supply and return RHR piping, and/or small bore lines. To more assuredly confirm that the system acoustics contribute to the behavior seen, more detailed acoustic modeling of the system would be required.

References:

C-1: Young, Hugh D. and Freedman, Roger A. *University Physics*. 9th Edition. Massachusetts: Addison-Wesley, 1996.

C-2: ASME Steam Tables. 6th Edition. New York: ASME, 1997.

Attachment D: Failure Analysis of Limit Switch Finger from Residual Heat Removal Gate Valve

Attached is a failure analysis performed by PSEG Services Company on the limit switch finger for the A loop RHR return line valve 1BCHV-F060A. An inspection performed in March 2004 noted that the finger had been found broken. The broken parts were retrieved from the drywell and provided to PSEG Services Company for failure analysis.

PSEG Services Corporation
Maplewood Testing Services
200 Boyden Ave, Maplewood, NJ 07040
tel: 973.761.1981

PSEG
Services Corporation

To John Barkhamer – Staff Engineer Nuclear
Design Engineering

April 27, 2004
Report No. 78671

FAILURE ANALYSIS OF LIMIT SWITCH FINGER FROM RESIDUAL HEAT REMOVAL GATE VALVE, HOPE CREEK GENERATING STATION

Requested by Heather Malikowski

Analysis conducted by Raymond E. Terek

INTRODUCTION

A failed 5 inch long by 1-3/8 inch wide by 3/8 inch thick Limit Switch Finger from a Residual Heat Removal (RHR) Gate Valve at Hope Creek Generating Station was submitted to the Metallurgy Group of Maplewood Testing Services to determine the cause of failure. It was reported in Work Order No. 70037702 that the Limit Switch Finger had experienced high vibration.

SUMMARY

1. The Limit Switch Finger from the RHR valve failed by a fatigue mechanism. Beach marks indicative of fatigue were evident on the mating fracture surfaces.
2. Microscopic examination of the fracture showed subsurface transgranular cracking and mechanical damage (strain lines) at the fracture surface; both are indicative of rubbing or banging together of the two sides of the fracture.
3. The failure occurred at a metallurgical notch (stress concentration) at a reduction in cross sectional area with sharp angles.
4. The Limit Switch Finger material was identified as carbon steel using an alloy analyzer confirming the requirement of ASTM A108 material as specified in the Bechtel Assembly Drawing No. 93-15122 Rev. F for Part No. 279.

VISUAL EXAMINATION

The Limit Switch Finger (Figure 1) failed at a reduction in cross sectional area in a slightly arced fracture surface. The wide section (mounting hole side of fracture) measured 1-1/4 inches wide and the narrow section (non-hole side of fracture) measured ¾ inches wide. The narrow and wide sections met at sharp angles (90°). Beach marks, indicative of a fatigue crack propagation, evident on the hole side of the failure, apparently originated at the 90° corner of the fracture surface (Figure 2) and progressed across the width of the failure.

VISUAL EXAMINATION (continued)

The narrow side of the fracture contained similar beach marks (Figure 3) and an area with a white paint like deposit. Mechanical damage was evident on one side of the fracture (Figure 4).

FRACTOGRAPHIC EXAMINATION

Fractographic examination performed on the 1 ¼" side (hole side) of the failure at the apparent origin area using a Scanning Electron Microscope (SEM) showed beach marks emanating from a sharp corner (Figure 5). No fatigue striations were observed. Examination of the origin area on the non-hole side showed the fracture initiated in a smooth area, passed through an area of fluorescing deposits, and finally the fracture surface became more fibrous (Figure 6) across the remainder of the failure. No fatigue striations were perceptible.

MICROSCOPIC EXAMINATION

Microscopic examination in the polished and etched condition of the fracture from the wide side (mounting hole side) of the failure, mounted on its side (transversely) showed cold work at the origin area (Figure 7). No fatigue spurs were evident on the fracture surface. Examination of the mounting hole showed subsurface discontinuity in the microstructure similar to a forging lap/crack (Figure 8).

Microscopic examination of a longitudinal sample taken on the narrow (non-hole) side of the failure showed transgranular cracking below a cold worked area of the fracture surface (Figure 9) indicative of rubbing or banging together of the two sides of the fracture which is supportive of a fatigue type mechanism. No fatigue spurs were evident emanating from the main fracture. The material microstructure showed lamellar pearlite in a ferritic matrix with numerous stringers or inclusions (Figure 10) that is considered normal for carbon steel. The inclusions were perpendicular to the fracture surface (Figure 11).

CHEMICAL ANALYSIS

Energy Dispersive Spectrometric (EDS) analysis of the white paint like deposit on the fracture surface of the non-hole side of the failure showed it consisted primarily of silicon, titanium, and manganese (Spectrum 1) and was apparently some type of coating.

EDS analysis of the fluorescing deposit observed in the fractographic analysis on the non-hole side of the fracture consisted primarily of calcium, iron, and tin (Spectrum 2) and was possibly solder and flux.

Heather Malikowski – Lead Engineer Nuclear
Engineering Programs

April 27, 2004
Report No. 78671

CHEMICAL ANALYSIS (continued)

The Limit Switch Finger material was identified as carbon steel using an alloy analyzer confirming the requirement of ASTM A108 material as specified in the Bechtel Assembly Drawing No. 93-15122 Rev. F for Part No. 279.

Senior Test Engineer

Metallurgist
Mechanical Division – Maplewood Testing Service

C: H. Malikowski – Lead Eng. –Nuclear N51
Alan Johnson – Engineering Supervisor – N29

FIGURE 1

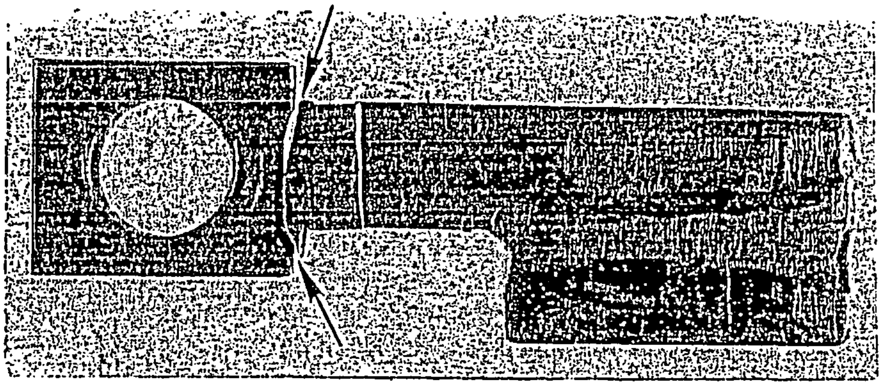


Photo No. 7195 Mag. 7/8x

Macrophotograph shows the failed limit switch finger. The failure occurred at a change in cross sectional area (between arrows) at sharp angles at the junction of the mounting hole side (left) and non-hole side of the limit switch finger. The non-hole side had been sectioned to facilitate examination of the fracture.

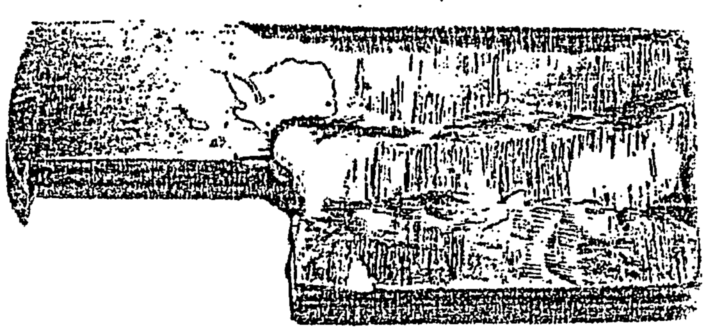


Figure 1 A: Mag. 1X

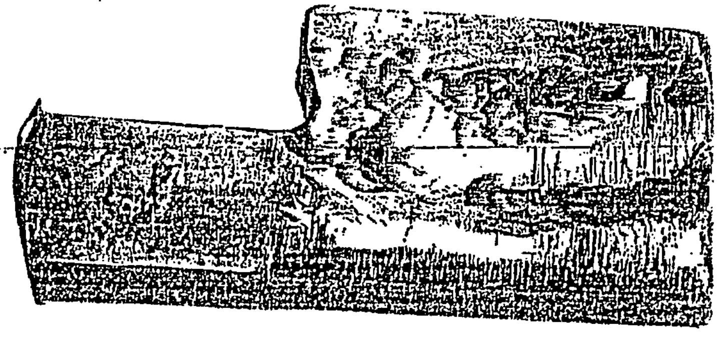


Figure 1 B: Mag. 1X

Photo shows other side of the part of the limit switch finger

Report No. 78671

FIGURE 2

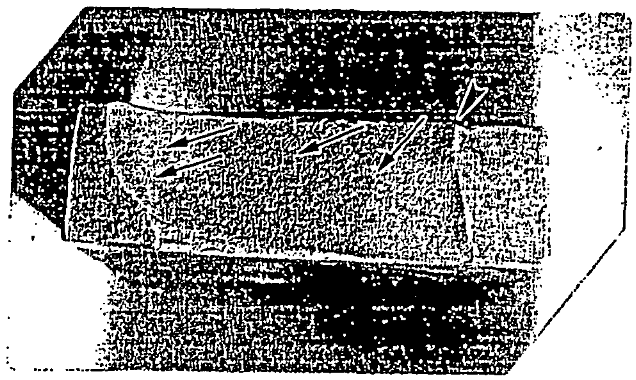


Photo No. 7198 Mag. 2x

Macrophotograph shows beach marks (arrows) that apparently started at the metallurgical notch (arrowhead) at the change in cross sectional area and sharp angles.

Report No. 78671

FIGURE 3

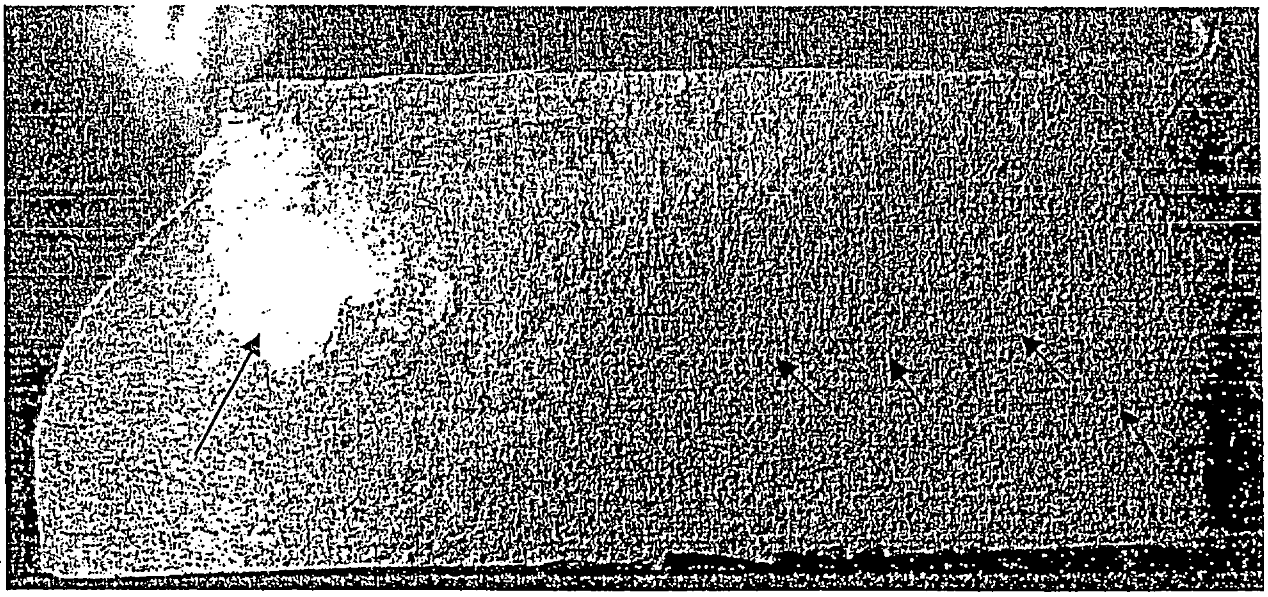


Photo No. 7199 Mag. 6x

Macrophotograph shows beach marks (arrows) and a white paint like deposit (left arrow) on the narrow side of the fracture that started in the lower right corner.

FIGURE 4

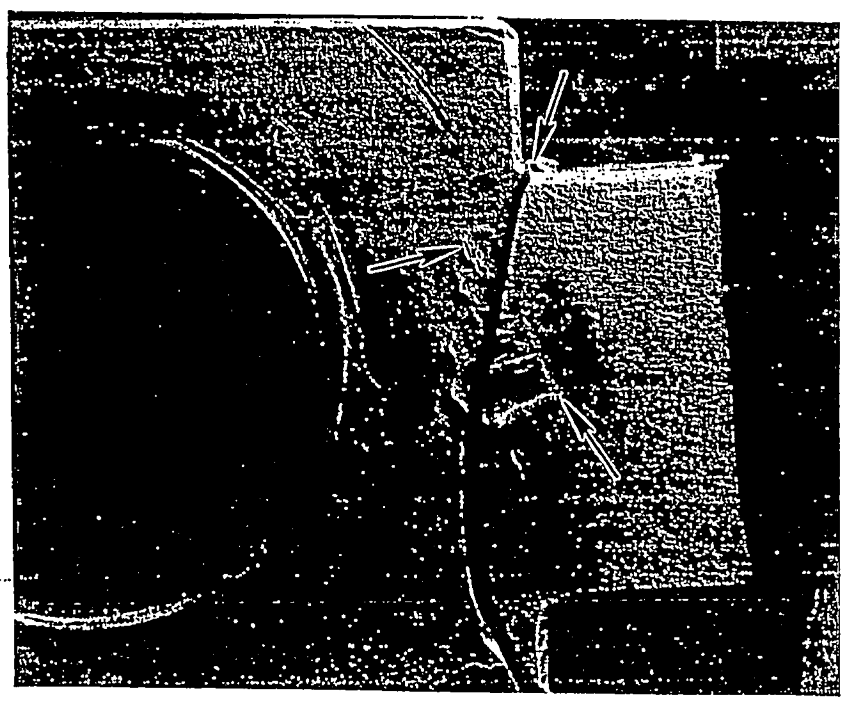


Photo No. 7200 Mag. 3x

Macrophotograph shows mechanical damage (arrows) on the side of the fracture. Note the sharp angle at the apparent fracture origin (upper arrow).

FIGURE 5

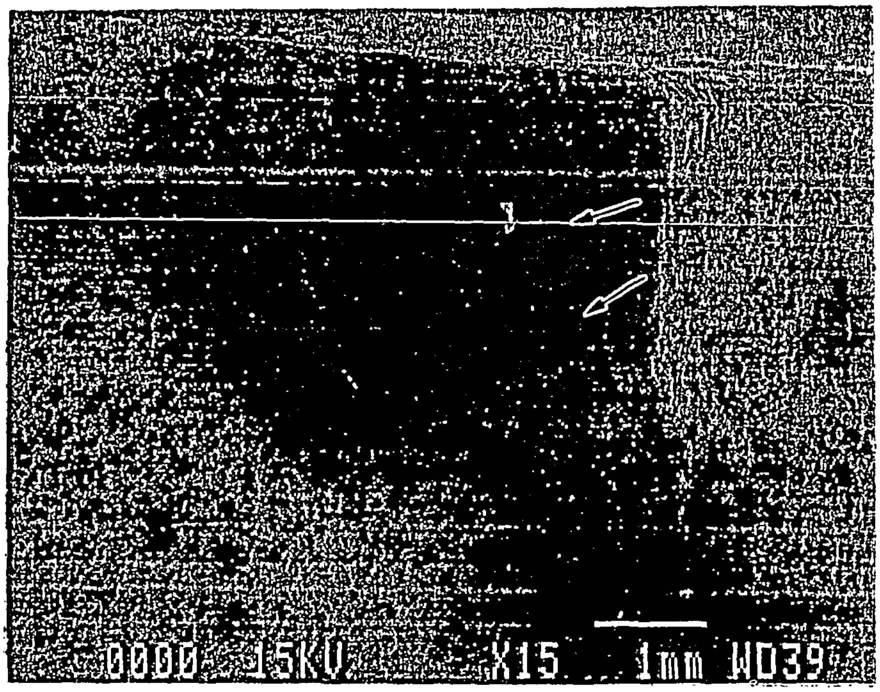


Photo No. 7201 Mag. 15x

SEM photo shows beach marks (arrows) on the narrow ¾" hole side of the fracture that started at the corner.

FIGURE 6

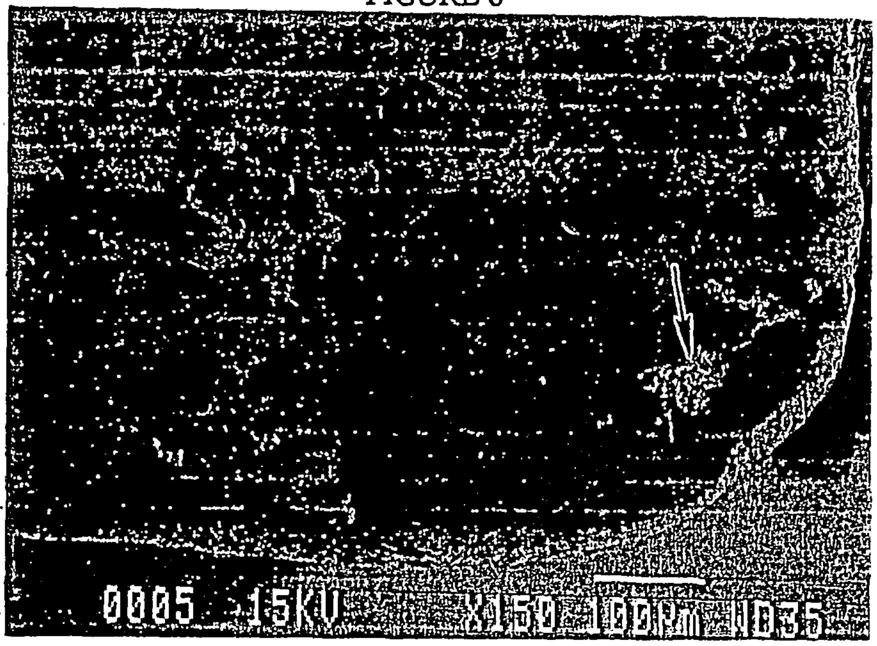


Photo No. 7202 Mag. 150x

SEM photo shows the apparent fracture origin at the lower right hand side of the photo on the narrow (non hole) side of the fracture. The fracture started out smooth, passed through a fluorescing (glowing) deposit (arrow), and exhibited a fibrous appearence.

FIGURE 7

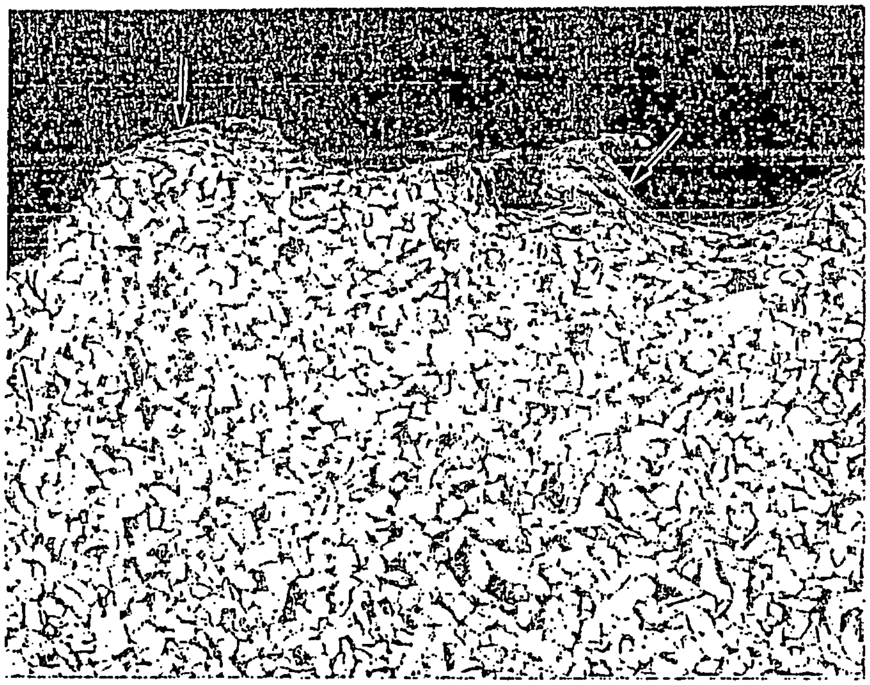


Photo No. 7204 Etchant: 2% Nital Mag. 100x

Microphotograph shows cold work or strain lines (arrows) at the origin on the hole side of the fracture.

FIGURE 8

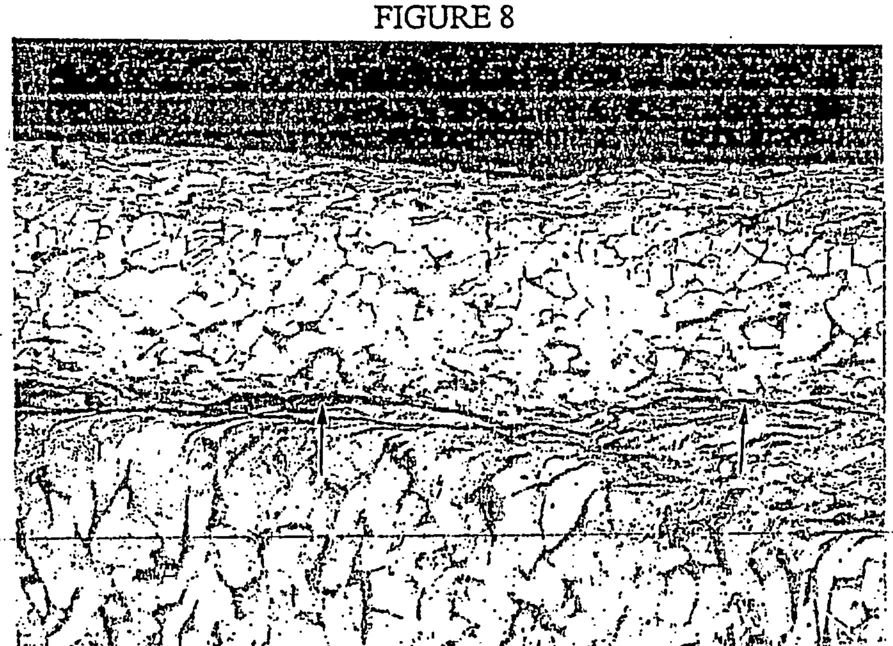


Photo No. 7203 Etchant: 2% Nital Mag. 200x

Microphotograph shows subsurface discontinuity in the form of a lap (arrows) below the mounting hole surface.

FIGURE 9

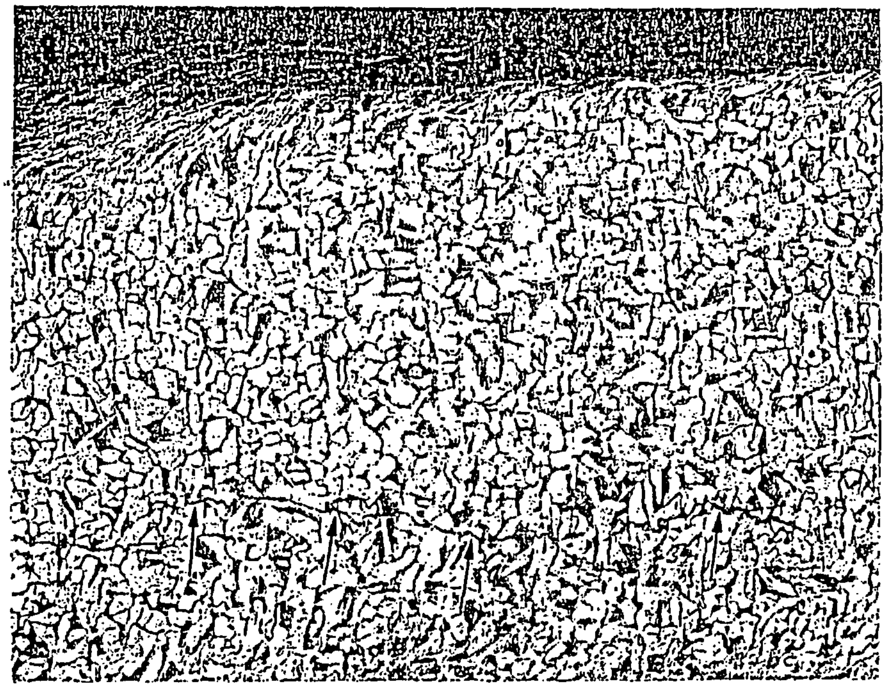


Photo No. 7205 Etchant: 2% Nital Mag. 100x

Microphotograph shows subsurface transgranular cracking (arrows) below cold work on the fracture surface on the narrow (non hole) side of the failure.

Photo No. 7207 Etchant: 2% Nital Mag. 500x

Figure 10: Microphotograph shows lamellar pearlite in a ferritic matrix with some stringers or inclusions (arrows) that is considered a normal structure.

FIGURE 11

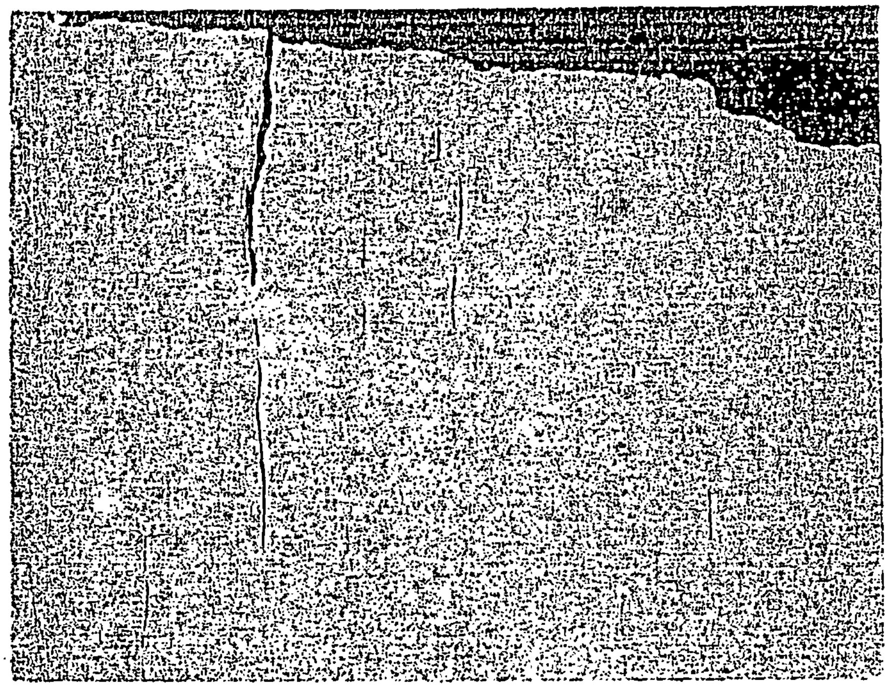
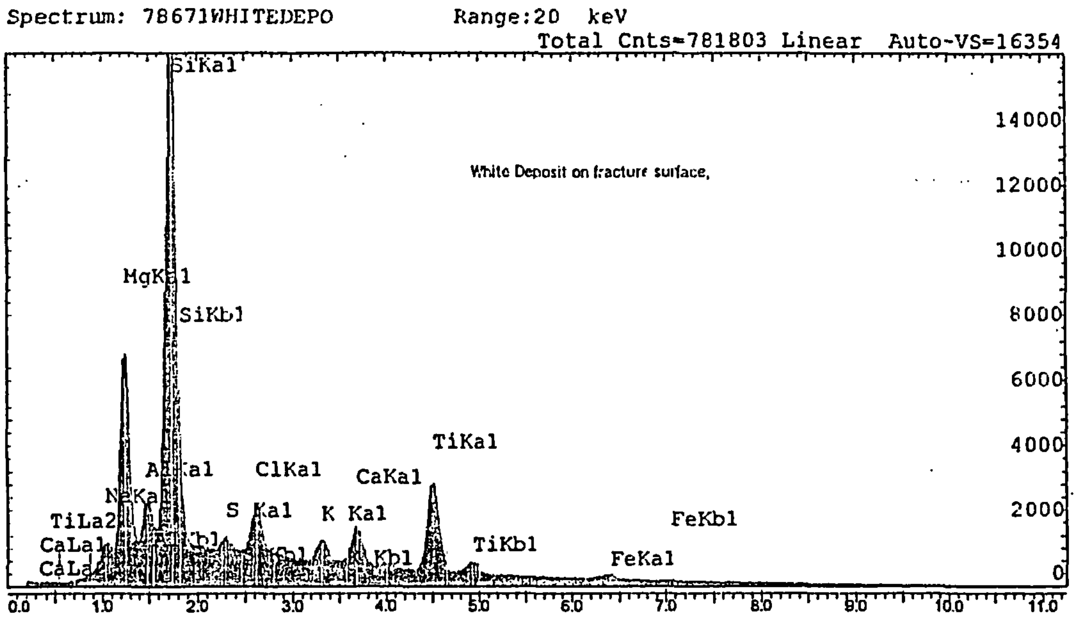


Photo No. 7206 Unetched Mag. 100x

Microphotograph shows the stringers were perpendicular to the fracture surface.

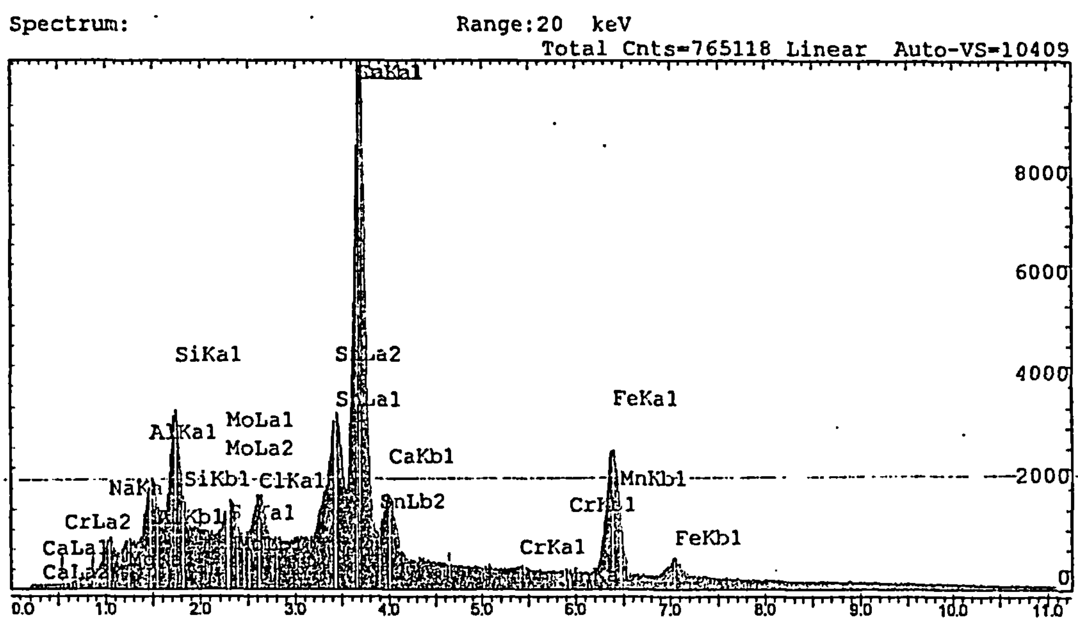
SPECTRUM 1



kev

EDS spectrum of the white, paint like deposit on the fracture surface shows the major elements silicon, titanium and magnesium.

SPECTRUM 2



kev

EDS spectrum of the fluorescing deposit at the corner of the fracture shows the major elements calcium, tin, and iron suggesting the deposit possibly from solder and flux.

Report No. 78671

Attachment E: Summary of Analysis Calculations

E.1 F050A Actuator Thread Shear Evaluation

E.2 F060B Valve Handwheel Natural Frequency Evaluation

E.3 F060 Block Valve Yoke and Operator Natural Frequency Estimate

E.4 Analysis Inputs for Scoping Finite Element Models

E.1 F050A Actuator Thread Shear Evaluation

In the inspection of the Hope Creek drywell, the pneumatic actuator for the F050A valve was found to be damaged. The actuator has a piston cylinder arrangement; where a cup-shaped cylinder having internal threads fastens to the external threads of a casting. A schematic of the arrangement is shown in Figure E.1-1. The cylinder was found completely separated from the casting during the inspection.

A detailed investigation of the cylinder and casting revealed that the threads were flattened in areas around the casting. It is unknown if the threads were previously undercut or not. Per the vendor, the threads are nominally UN 5.125-12-2A/B, as documented in Attachment B.8 of Engineering Evaluation H-1-BB-CEE-1830. The limiting nominal diameters for both the external and internal threads are listed in Table E.1-1. The as-found dimensions of the threads were measured and are also listed in the table. The table shows that there was little thread engagement in the joint in the as-found condition. The minimum interference allowed in a UN 5.125-12-2A/B joint is 0.063 inches per Reference E.1-1.

Description of Analysis

The stripping load for the limiting nominal condition of a threaded joint manufactured to the standards of Reference E.1-1 is calculated using the methodology described below.

Shear Area

The stripping loads for the internal threads on the cylinder and the external threads on the casting are calculated by first computing the shear areas for the threads. The shear areas are computed using the methodology in Reference E.1-1. The inputs used to compute the shear area for the limiting nominal threads are listed in Table E.1-2. The computed shear areas for the threads on the cylinder and casting are and listed in Table E.1-3.

$$AS_s = \pi \cdot L_e \cdot n \cdot K_{n,\max}\left(\frac{1}{2n} + 0.57735\left(E_{s,\min} - K_{n,\max}\right)\right)$$

$$AS_n = \pi \cdot L_e \cdot n \cdot D_{s,\min}\left(\frac{1}{2n} + 0.57735\left(D_{s,\min} - E_{n,\max}\right)\right)$$

Stripping Load Calculation

The stripping load in the threads is computed using the empirical methodology described in Reference E.1-2. The empirical equations used contain factors that take into account:

- Nut dilation (C_1),
- External thread bending (C_2), and

- Internal thread bending (C_3).

Nut dilation is the tendency of the nut of a threaded joint (cylinder in this case) to expand outwardly. Thread bending reduces the shear area of the threads and increases the likelihood of nut dilation. Taking these factors into account reduces load required to strip the threads.

Assuming that the cylinder and casting each have an ultimate strength of 58 ksi, the required stripping load for the nominal thread condition is listed in Table E.1-4. The table shows that the minimum stripping load of a threaded joint manufactured to the specification in Reference E.1-1 is 99.5 kips.

$$BSL = U_s \cdot AS_s \cdot C_1 \cdot C_2 \cdot 0.6$$
$$NSL = U_n \cdot AS_n \cdot C_1 \cdot C_3 \cdot 0.6$$

U_s = ultimate strength of the casting, 58 ksi

U_n = ultimate strength of the cylinder, 58 ksi

$$C_1 = -\left(\frac{s}{D}\right)^2 + 3.8 \cdot \frac{s}{D} - 2.61$$

Where:

s = measured outside diameter of cylinder, 5.5 in
D = nominal thread diameter, 5.125 in

$$C_2 = 5.594 - 13.682R_s + 14.107R_s^2 - 6.057R_s^3 + 0.9353R_s^4$$

Where:

$$R_S = \frac{U_n \cdot AS_n}{U_s \cdot AS_s}$$

$$C_3 = 0.897$$

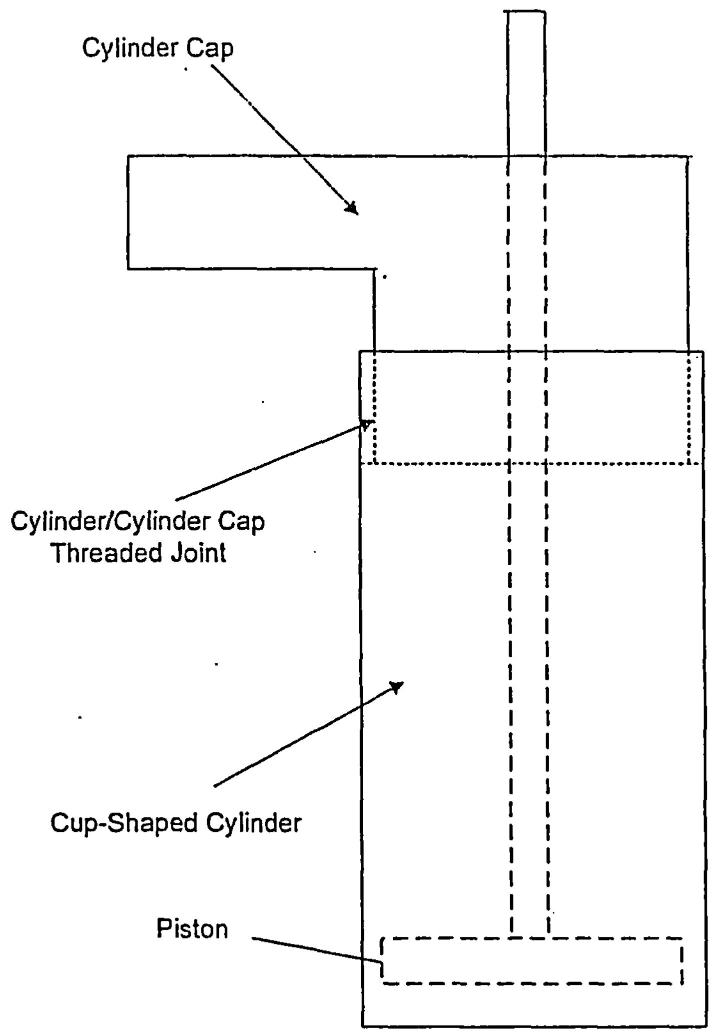


Figure E.1-1. F050A Pneumatic Actuator Schematic

Table E.1-1. Comparison of Limiting Thread Dimensions and As-Found Thread Dimensions

Parameter	Limiting Nominal Condition	As-Found Condition
External Thread Major Diameter (in)	5.1116[1]	5.078[2]
Internal Thread Minor Diameter (in)	5.053[1]	5.081[2]

1. Taken from Reference E.1-1.
2. Average of two measurements made 90° apart.

Table E.1-2. Inputs for Calculating Thread Shear Area

Parameter	Limiting Nominal Case[1]
Internal Thread Minor Diameter ($K_{n,max}$)	5.053 in
Internal Thread Pitch Diameter ($E_{n,max}$)	5.0796 in
External Thread Major Diameter ($D_{s,min}$)	5.1116 in
External Thread Pitch Diameter ($E_{s,min}$)	5.0622 in
Engagement Length (L_e)	1 in
Threads Per Inch (n)	12

1. Limiting dimensions for a threaded joint per Reference E.1-1.

Table E.1-3. Computed Thread Shear Areas

Parameter	Limiting Nominal Case
Internal Thread Shear Area (AS_n)	11.59 in^2
External Thread Shear Area (AS_s)	8.95 in^2

Table E.1-4. Computed Thread Shear Loads

Parameter	Limiting Nominal Case
Internal Thread Stripping Load (NSL)	114.4 kip
External Thread Stripping Load (BSL)	99.5 kip

References

E.1-1 ANSI B1.1-1989, *Unified Inch Screw Threads (UN and UNR Thread Form).*

E.1-2. Alexander, E. M., *Analysis and Design of Threaded Assemblies.* Pennsylvania: Society of Automotive Engineers (Paper No. 770420), 1977.

E.2 F060B Valve Handwheel Natural Frequency Evaluation

The natural frequency is estimated using the simple formula below for oscillation of a mass at the end of a cantilever:

$$f = (1/2\pi)\sqrt{3EIg/WL^3}$$

where

f = natural frequency of the first mode of vibration, Hz
E = Young's modulus for steel, pounds force per square inch
I = moment of inertia of the cantilever section, in^4
g = gravitational constant, 386.4 in-pound mass/sec^2 –pound force
W = mass at the end of the cantilever, pounds-mass
L = length of cantilever (between mass center of gravity and fixed end), inches

The dimensions determined by scaling photographs and the weight can be estimated from the volume of the components. For estimation purposes, the following ranges of values are used:

Parameter	High Value	Low Value
E	30,000,000 psi	28,000,000
I	0.25 in^4 (for 1.5" diameter shaft)	0.12 in^4 (for 1.25" diameter shaft)
W	30 pounds	25 pounds
L	8 inches	6 inches

Using the above ranges, the natural frequency can vary between about 80 Hz to 200 Hz.

E.3 F060 Block Valve Yoke and Operator Natural Frequency Estimate

Background

The Hope Creek F060 block valves are apparently subjected to vibration of the RHR discharge lines due to their connections to the Recirculation System (pump) discharge lines. There is a potential that the lines are excited at multiples of the Recirculation pump vane passing frequency. Therefore, it is desired to estimate the natural frequency of the valve's yoke and manual operator assembly.

Purpose

Estimate the natural frequency of the 12-inch gate valve's yoke/operator assembly using the following information:

- Anchor/Darling Assembly Drawing 93-15122, Revision F (Reference E.3-1)
- Anchor/Darling Seismic Calculation No. E-6162-S-10 (Reference E.3-2)
- Walkdown photo of actual valve

Evaluation

The Anchor/Darling seismic calculation uses two plausible models for estimating the natural frequency of the yoke/operator assembly. The calculated natural frequencies are 92 Hz for a cantilever beam model, and 122 Hz for a frame bending model (see p. 24 of Reference E.3-2). However, the weights and dimensions used in this calculation are not consistent with the as-installed configuration of the valve. For example, the calculation uses an operator weight of 1375 lbs., apparently for a motor operator. This valve was actually installed with a handwheel operator (estimated weight about 300 lbs). The total weight of the yoke/operator assembly, therefore, is estimated at 490 lbs, vs. the 1565 lbs. used in the seismic calculation.

The higher weight is very conservative (and therefore acceptable) for a seismic qualification calculation, but its use for estimation of the actual natural frequency of the yoke/operator assembly is not accurate. Additionally, based on the walkdown photos, the opening of the yoke cutout height appears larger (taller) than assumed in the seismic calculation, and the effective length from the base to center of gravity for the cantilever beam model is shorter than assumed in the seismic calculation. Further, the seismic qualification calculation used cross sectional properties of the yoke at its widest point. The yoke tapers to a smaller cross section with increasing distance from the valve disk.

The following evaluation provides a parametric study of the effect of changing the mass, cross sectional properties, and effective length of the cantilever on the calculated natural frequency:

Natural Frequency Case 1: Cantilever Beam model--assumes concentrated mass

From Calc p. 24, fn = (1/2π)((3EIg)/(WL^3))^1/2

constants:
E = 29.5E6
g=386.4
variables: I, W, L

Estimate moment of Inertia about weak axis:

From Calc p. 19: I = 0.5*((Ro^4)-(Ri^4))*0.283

	Ro	Ri	I	
	4.4	3.65	28	at top of cutout--too conservative
	5	4.25	42	near top of cutout--probably too conservative
	6	5.25	76	
	7	6.25	124	
	8	7.25	189	
used in calc	8.44	7.69	223	at base of cutout

	I	W	L	fn	
used in calc	223.3	1565	24.5	92	
	223.3	490	24.5	164	L may be too high for real cg
	223.3	400	24.5	181	L may be too high for real cg
	28	490	20	79	I at top of cutout--too conservative
	42	490	20	96	I near top of cutout--too conservative
	76	490	20	130	
	124	490	20	166	
	189	490	20	204	
	223.3	490	20	222	I at base of cutout

Natural Frequency Case 2: Frame-bending model

From Calc p. 24, fn = (1/2π)((12EIg)/(WL^3))^1/2

Same constants, and W is the same, but I and L are different:
L is closer to 14 inches (based on photo), vs. 12 used in calc

	I	W	L	fn	
used in calc	11.596	1565	12	122	
	2	490	14	72	I at top of cutout--too conservative
	4	490	14	102	
	6	490	14	124	
	11.596	490	14	173	I at base of cutout

Conclusions

As shown in the above parametric evaluation, the valve's yoke/operator assembly is expected to have natural frequencies between about 100 Hz to 200 Hz.

E.4 Analysis Inputs for Scoping Finite Element Models

Valve	Finite Element Model	Component	Quantity	Value	Reference (Note 1)
F060 Valve	Stem Only	Material Properties (SA 476-410 at 200°F)	Elastic Modulus	28.5×10^6 psi	ASME Code
			Poisson's Ratio	0.30	Assumed
			Density	0.286 lb/in^3	Assumed
F060 Valve F050 Valve	All Other Components	Material Properties (Carbon Steel at 200°F)	Elastic Modulus	28.8×10^6 psi	ASME Code
			Poisson's Ratio	0.30	Assumed
			Density	0.284 lb/in^3	Assumed
F060 Valve	Stem / Indicator Rod / Indicator Arm Model	Stem	Height Above Stem Nut	12 in	Scaled
			Diameter	2.25 in	A/D Dwg. 025B60360
		Indicator Rod	Length	7 in	A/D Dwg. 025B60360
			Diameter	0.75 in	A/D Dwg. 146A10197
		Indicator Arm	Length	6 in	Measured
			Width/Thickness	0.5 in	Measured
			Height Above Stem	5.25 in	Measured
	Gearbox Cover / Stem Protector Model	Gearbox Cover	Diameter	23.5 in	Information provided by Anchor/Darling (A/D)
			Thickness	0.25 in	
		Stem Protector Pipe	Length	19.5 in	A/D Dwg. 334B60361
			Diameter	3.5 in nom	A/D Dwg. 334B60361
			Schedule	Sch 40	A/D Dwg. 334B60361
			Slot Length (full width)	12.5 in	A/D Dwg. 334B60361
			Slot Width (full)	1 in	A/D Dwg. 334B60361
			Slot Angle to Bracket	35 deg	A/D Dwg. 833C20067
			Slot Height Above Cover	3.5 in	A/D Dwg. 334B60361

Valve	Finite Element Model	Component	Quantity	Value	Reference (Note 1)
		Limit Switch Bracket	Height	15.5 in	A/D Dwg. 433C20066
			Width	7.5 in	A/D Dwg. 433C20066
			Thickness	0.375 in	A/D Dwg. 433C20066
			Height Above Cover	2 in	A/D Dwg. 833C20067
		Limit Switches	Mass	8.4 lb (total)	VTD PP302-0368
F050 Valve	Air Operator / Bracket Model	Dimensions for this model were taken from field measurements as described in Section 6 of this report or were scaled and/or estimated from photographs included in Attachment A to this report.			

Notes:
1. Dimensions identified as "scaled" were either scaled or estimated from photographs included in Attachment A to this report.

Attachment F: Causal Factor Evaluations for Observed Degradation

Table F-1. Causal Factor Evaluation for Degraded Conditions

Possible Cause	Existing Data Supporting Cause / Existing Data Disproving Cause	Data Required to Confirm Cause / Data Required to Disprove Cause	Comment
Notification 20182421 – Noise heard in north pipe chase			
Disc in valve F050A is "chattering"	• Sound checks suggest noise is originating in A RHR return line. • Likely no differential pressure across valve during operation if valve F015A is leak tight. • Pipe vibration occurs at this location on the order of 0.2 g's in each direction	• Damage to valve seat observed either by failure of leak test or visual observation during the next refueling outage	
	• F050A valve was leak tight when tested in April 2004.	• Dynamic analysis which shows that the pipe vibrations or hydraulic conditions are insufficient to cause chattering of disc.	
Handwheel is loose on valve F060A	• Sound checks suggest noise is originating in A RHR return line. • Knocker handwheel design allows handwheel to rotate a short distance during operation. • One group of personnel report that when handwheel was manually rotated to cause contact that the noise in north pipe chase was comparable to banging during operation. • Pipe vibration occurs at this location on the order of 0.2 g's in each direction. • Evidence of fretting and wear indicate handwheel is vibrating.	• Videotape of the valve in service if the noise returns following October 2004 outage	

Possible Cause	Existing Data Supporting Cause / Existing Data Disproving Cause	Data Required to Confirm Cause / Data Required to Disprove Cause	Comment
	• One group of personnel report that the noise from the handwheel does not sound like the banging during operation. • The handwheel was securely lashed in place with lockwire during the March 2004 forced outage and the sound returned in May 2004.	• If handwheel is removed during the next refueling outage and the noise returns, this rules out the handwheel.	
F060A Valve Stem Protector Assembly is Deflecting	• Sound checks suggest noise is originating in A RHR return line. • Noise seems to occur when limit switch indication problems are reported. • Modal analysis shows that the stem protector plate has several modes of deflection that could be excited by typical pump pulsation frequencies	• Videotape of the valve in service if the noise returns following October 2004 outage. • Condition of the stem protector or cover plate in the October 2004 found to be degraded	
	• None, although it is not clear why the F060B valve would not have the same issue (no noise has been attributed to the F060B valve but it has a comparable geometry)	• "Ring testing" shows that the assembly does not have an actual modal response in the typical pump pulsation frequency range	

Possible Cause	Existing Data Supporting Cause / Existing Data Disproving Cause	Data Required to Confirm Cause / Data Required to Disprove Cause	Comment
Actuator for valve F050A has damaged housing that was banging	• Sound checks suggest suggests noise is originating in A RHR return line. • Actuator housing found damaged and free to translate up and down. • Pipe vibration occurs at this location on the order of 0.2 g's in each direction. • One group of personnel report that when housing was manually raised and lowered to cause contact that the noise in north pipe chase was comparable to banging during operation.	• Videotape of the valve in service if the noise returns following October 2004 outage • If October 2004 refueling outage inspection shows that the housing has again detached, that would support the housing as the source of the May 2004 noise.	
	• Loose actuator was replaced with new part and the noise returned. • No degradation was observed on the OD of the housing cylinder that suggests the housing was impacting other equipment	• If October 2004 refueling outage inspection shows that the housing is in its as-designed position, that would rule out the housing as the source of the May 2004 noise.	
F060A valve disk is banging into valve internals	• Sound checks suggest noise is originating in A RHR return line. • Local pipe experiences accelerations	• Damage to valve seat observed either by visual observation of the valve internals during the next refueling outage	
	• None, although it is not clear why the F060B would not be experiencing the same phenomenon.	• No damage seen during visual inspection	

Possible Cause	Existing Data Supporting Cause / Existing Data Disproving Cause	Data Required to Confirm Cause / Data Required to Disprove Cause	Comment
F060A valve handwheel/pinion shaft are vibrating as a beam	• Sound checks suggest noise is originating in A RHR return line. • In prior outages the shaft was found sheared, indicating that the shaft is subject to vibration. • Simple modal analysis shows that the handwheel/shaft may have a natural frequency in the vane passing frequency range.	• Videotape of the valve in service if the noise returns following October 2004 outage. • Condition of the pinion shaft in the October 2004 found to be degraded	
	• None, although it is not clear why the F060B valve would not have the same issue (no noise has been attributed to the F060B valve but it has a comparable geometry)	• "Ring testing" shows that the assembly does not have an actual modal response in the vane passing frequency range	
Notification 20182400 – Handwheel fell off valve F060B			
Long term wear due to normal pipe vibrations	• The amount of wear on handwheel is significant, unlikely to have occurred during a brief period of time. • This is a repeat failure. The handwheel has fallen off at least four times previously.	• Videotape of the valve in service for evidence of severe vs. normal vibration.	
	• None	• If severe wear is seen on hub or handwheel in the October 2004 refueling outage, this would indicate that the vibration is high (valve would have seen 6 months of operation)	
Significant wear during short period from unusually high vibrations	• Valve handwheel was cracked. It is not clear how normal vibration could cause this crack, although the crack may have occurred when the valve is manually operated (handwheel is knocker type).	• Videotape of the valve in service for evidence of severe vs. normal vibration.	

Possible Cause	Existing Data Supporting Cause / Existing Data Disproving Cause	Data Required to Confirm Cause / Data Required to Disprove Cause	Comment
	• Piping vibrations measured at this location after the handwheel was reinstalled are not indicative of high vibration	• If severe wear is seen on hub or handwheel in the October 2004 refueling outage, this would indicate that the vibration is high (valve would have seen 6 months of operation)	
Notification 20182396 – Valve F060A limit switch actuator arm and rod are broken and missing Notification 20182395 – Valve F060B limit switch actuator arm and rod are broken			
Thermal expansion of valve stem causes switch finger to contact stem protector slot	• There is a short distance between the limit switch finger and the top of the stem protector slot	• Videotape of the valve in service for evidence of thermal expansion.	
	• Degradation appears to be from the side of the slot not the top as shown in drywell photos. • The distance the finger would have to travel to contact the top of the slot is too far to be explained by thermal expansion. • The thermal expansion occurring now is the same that has always occurred. • The switch apparently failed again in May 2004 after reportedly being re-set at a lower elevation in the March 2004 outage.	• Degradation recurs after the limit switch is reinstalled at a lower position. NOTE: This has apparently recurred, as the switch reportedly failed in service in May 2004. If the evaluation of that failure (during the next refueling outage) shows that the failure of the re-set switch is the same as that experienced earlier, that would make this possible cause an unlikely one.	
Vibration of the RHR piping caused stem protector assembly to vibrate and	• The stem protector assembly likely has a mode shape that would interfere with the switch at a natural frequency in the vane passing range. • The F060A and F060B valves have similar stem protector geometry and have similar failures.	• Videotape of the valve in service for evidence of contact between stem protector and limit switch.	

Possible Cause	Existing Data Supporting Cause / Existing Data Disproving Cause	Data Required to Confirm Cause / Data Required to Disprove Cause	Comment
contact the side of the switch	• None.	• "Ring testing" shows that the assembly does not have an actual modal response in the vane passing frequency range	
Notification 20182397 – Valve F050A damaged actuator housing			
Insufficient thread engagement of original parts allowed normal vibration and service loads to defeat threaded connection	• Parts were found out of tolerance with respect to thread size; loss of set screw would result in reduced thread engagement. • Structure likely has "swaying" mode of displacement with a natural frequency in the vane passing frequency range.	• Part was replaced with new part checked to ensure it had proper thread engagement. If no damage recurs, this supports this possible cause.	
	• None.	• "Ring testing" shows that the assembly does not have an actual modal response in the vane passing frequency range • A repeat of the damage seen in March 2004 to the new, properly threaded F050A actuator.	
Vibration caused correctly threaded component to slowly wear, leading to failure	• Gouge surface becomes shallower with increasing distance from nominal contact point, indicating that cap screw shortened over time rather than failed at all once. • The gouge surface appears polished, indicative of high cycle, low stress vibration-induced wear. • Structure likely has "swaying" mode of displacement with a natural frequency in the vane passing frequency range.	• Continued damage under vibration loads leading to failure after many years would confirm this cause.	
	• None.	• Lack of damage after many years of service would refute this cause.	

Possible Cause	Existing Data Supporting Cause Existing Data Disproving Cause	Data Required to Confirm Cause Data Required to Disprove Cause	Comment
Vibration "shook" cylinder off its mounting	• Pipe vibration occurs at this location on the order of 0.2 g's in each direction. • Structure likely has "swaying" mode of displacement with a natural frequency in the vane passing frequency range.	• Part was replaced with new part checked to ensure it had proper thread engagement. If damage recurs, this supports this possible cause.	
	• Properly threaded connections of this size are nominally capable of withstanding 100 kip loads; it is inconceivable that the applied loads approach this amount.	• If replaced F050A actuator shows no damage, this reduces the likelihood of this as a potential cause.	

Attachment G: Tech Issues Report on North Pipe Chase Noise

This attachment is excerpted from a Tech Issues evaluation updated on June 14, 2004. It is included in this evaluation to document the status of the tech issues effort performed as of that date.

FORM 1 NC.ER-DG.ZZ-0006(Z)

(Page 1 of 1)

TECHNICAL ISSUES FACT SHEET

Title of Issue:

Responsible Supervisor: Mark D. Pfizenmaier
Problem Statement: An unexplained "clunking" noise, irregular in rhythm, was noted coming from the A RHR piping by HV FO15A which is located in the pipe chase room 4329.

Goals(s): To determine cause of noise, evaluate significance and determine corrective actions.

Design Information and References:

During shutdown cooling the flow from the A RHR heat exchanger can be directed to the A recirc pump discharge supplying flow to the A jet pumps.
This line has an isolation valve just outside containment F015A. Once inside containment, the line makes a 90 degree turn to the right . The next valve in line is a checkvalve F050 with an air actuator used for stroking the checkvalve for testing. This is followed by F060 which is an inboard manual isolation. From here the line turns up, then doubles back above the valves then turning toward the recirc pump discharge line. The recirc pump discharge line runs vertical then tee's at the jet pump supply header which feeds the 5 lines into the vessel to the A jet pumps. An audible noise on Channel 6 (ve7935C/D) of the loose parts monitor was noted which is associated with the A Recirc loop and is installed on the jet pump riser at the vessel nozzle number N2J. This is the only riser on the A side with this type of sound monitoring.

The pipe spec from F015 to the recirc pipe is DLA (900#, Carbon Steel impact tested, nuclear component class 1)
The pipe spec for the RHR line leading up to F015 is GBB (300#, carbon steel, nuclear class 2).

M-43-1 sh1
M-51-1 sh2
J-J1705-1
J-J1703-1
PJ803-0003
Licensing Basis Information and References:

Facts/Assumptions and Source/Reference Documents

A RHR SDC noise – notif 20181388
Although not reported until later, the noise was first noticed on 3/13 between 8 and 9 am. Based upon E mails from others who had entered the room, no noise was noticed up thru March 8. The first recirc flow change on the 13th was at 9:27. Later, at approx 1300, one control rod was inserted and total core flow was raised from 97 Mlb/hr to 98 Mlbhr to allow for weekly control rod exercise testing. The noise in the pipe chase was then reported to the control room. It is not known if the noise is associated with the recirc flow increase. The weekly rod exercise was completed later on day shift 3/14.

The following data collection activities were performed on nightshift 3/13/04 to assess operability and extent of condition:

At the time of the initial discovery, total core flow was approx 98 Mlb/hr and A Recirc pump speed was approx 1484 rpm.

The noise was audible on Channel 6 of the loose parts monitor which is associated with the A Recirc loop and is installed on the jet pump riser at the vessel nozzle number N2J. Channel 6 is 'A' Rx Recirc Line 300 130, Rx Recirc Riser and Channel 5 is 'B' Rx Recirc Loop 120 azm 130 elev, Rx Recirc riser. This is for jet pumps number 17 & 18. The channel 6 vibration set point is 1.9G, which is equivalent to 134.4 MVRMS at the input to the amplifier. The impact set point for loose parts is 0.5 ft lb (calc SC-BB-0520). The sensors are located in the drywell up on 130 elevation, at azimuth 275.

The daily jet pump surveillance OP-ST.BB-0001was performed upon discovery that the channel was associated with a jet pump riser to determine tech spec operability. The surveillance was completed satisfactorily at 21:00 and all jet pumps are operable.

A small increase in recirc pump speed was performed at 20:50 to maintain 100% power. Core flow was raised to 98.2 Mlb/hr and A recirc speed was increased to 1486 rpm. The noise was monitored locally in room 4329 and on the loose parts monitor. The metallic rapping noise did not change appreciably, however the overall background noise and vibration level in the room increased slightly.

A small decrease in recirc pump speed demand was performed at 22:57 to maintain 100% power. Core flow was not changed appreciably. A recirc speed remained at approx 1486 rpm. The piping noise was monitored locally in room 4329 and on the loose parts monitor. When the room was entered, prior to the flow change, the metallic rapping noise was judged to be occurring on a quicker frequency than before. The background noise and vibration level in the room did not change appreciably with the recirc flow change.

The WCS, SM, STA and shift engineer independently listened to the noise at various times during the early part of the shift. The consensus was that it is being caused by mechanical means (metal hitting metal) and not due to a water hammer event or other system hydraulic event such as pump cavitation, steam leak, etc. The piping at the F015A is cool to the touch, indicating that there is no leakage through the valve from the recirc system. DW floor drain leakage is stable. Recirc pump vibrations are steady and within the normal range. The A Recirc is not operating in a resonance region.

System engineering arrived on site at approx 23:00 and was briefed by the shift manager and shift engineer. The engineer was asked to validate the assessment that the noise is due to mechanical means and not due to an in progress hydraulic event and to assess any other actions that should be taken.

System engineering verified source of sound was the F015A line 12" DLA-069. This was done by listening to the pipes using a screwdriver. Sound was very strong by F015A and vibrations from noise could be felt.

Channel 5 came in and the WIN Team performed trouble shooting [2081515]. The WIN Team swapped cables for channel 5 and the cleared with no noise present or vibration alarms coming in the control room. The channel 5 issue appears to have no relation to the RHR piping noise.

Alternate means to obtaining data were considered. This included acoustic reading (hand held sound level meter, and ultrasonic). Neither provided useful data.

If the F050A is chattering, the valve position indication in the control room should be changing in the control room. As the indication is not, it is not believed to be chattering.

The following discussion was received concerning various valves.

From: Nealon, William J.
Sent: Tuesday, March 16, 2004 1:04 PM
To: Groves, Douglas M.
Cc: McCollum, Douglas J.
Subject: Open items from meeting today

Valve Engineering:
1. Write-up for disc flutter of 1BCHV-F122A and 1BCHV-F050A. Valve 1BCHV-F050A is a check valve with a disc seating at an angle and full RCS pressure on the downstream side of the disc. Valve 1BCHV-F122A is a small globe valve with full RCS pressure above the disc. With full system pressure above the discs for both valves, it is felt that the discs are solidly into the seat and should not be moving. The possible cause of the noise should not be from disc flutter on either valve.

2. Visual Inspections during shutdown:
H1BC -1-BC-V183 (1BCZS-F060) - Manual Isolation for Shutdown return line. Check this manual valve for handwheel being loose, limit switch looseness, yoke looseness, bonnet joint leakage, and a general condition. Check for any loose components contacting valve.

H1BC -1BCV-111 (1BCHV-F050A) - Check valve with an air operator. Inspect the external accessories for this check valve. Verify tight mounting fasteners for the SOV, air operator, disc arm linkage. Check the hanger arm to linkage connection for signs of shaft flutter or wear. Verify no external components leaning against or contacting valve.

This valve will be stroked as part of the shutdown IST procedure.

And also supplied by the valve group:

Valve H1BC -BC-HV-F050A (H1BC -1BCV-111) is a 12" 900# Atwood & Morrill testable swing check valve with disc seating at an angle off of perpendicular. This valve is the RHR Loop "A" return to Recirc check valve. The valve is a containment isolation valve for penetration P4B and is also a RCS pressure isolation valve. During normal plant operation the valve is closed to prevent over pressurization of the RHR piping. The Reactor Coolant System pressure and the weight component of the disc (due to its inclined position) hold the valve closed on its seat.

Valve H1BC -BC-HV-F122A (H1BC -1BCV-117) is a 2" 1500# Rockwell Edwards Y-pattern globe valve with an air actuator. This valve is the bypass valve around the H1BC -BC-HV-F050A valve. It is a containment isolation valve for penetration P4B and is also a RCS pressure isolation valve. The valve is normally closed during plant operation to prevent over pressurization of the RHR piping. It is only opened in the initial stages of shutdown cooling initiation to warm-up of the RHR header. The valve is installed such that full RCS pressure is above the disc, which acts to press the disc closed.

With full reactor pressure above the discs on both valves, the valves are solidly pushed into their seats and should not flutter. Therefore, it is unlikely that the noise emanating from the RHR piping outside of Penetration P4B is caused by disc movement in either H1BC -BC-HV-F050A (H1BC -1BCV-111) or H1BC -BC-HV-F122A (H1BC -1BCV-117).

Oscillations in Jet Pump DP and Recirc Flow oscillations to RPM increase, during the event were compared to two weeks earlier. No noticeable changes were observed.

Operating Experience/History and Sources:

Valve engineering looked at check valve F050A history file and found no history of problems with this valve.

GE SIL 600 "Increased Containment Noise and Vibration at Increased Recirculation Pump Speed" (May 1996) was reviewed. Susquehanna concluded the noise was due to the RHR testable check valve not being properly seated. This occurred when the pump speeds were between 1525 and 1550 rpm.

A phone call was placed to GE (Bob Ross 408-925-6906). Bob recalled receiving a phone call from TVA regarding a similar event. He believed the source of the noise was eventually attributed to the F060 valve's gate resonating with the recirc pump speed. Brown's Ferry personnel could not recall the event occurring there. It is likely Bob Ross confused the plant that it occurred at.

Acoustic Monitoring Results:
Based upon observations of the loose parts monitoring system (on 3/17) and performing acoustic monitoring (on 3/18 at 100%, during the down power, at the lower power, and again at 100%) in the north pipe chase room (4329) the following were noted:

- The source of the noise is unlikely to be in the reactor vessel.
- The source of the noise is unlikely to be in jet pump.
- The source of the noise is unlikely to originate from a pipe hanger or structural member.
- The source of the noise is unlikely to a FME item.
- The noise is most likely to be originating from inside the drywell.
- The noise is clearly originating from only the "A"RHR shutdown cooling line.
- The noise is metallic in nature.
- The source of the noise is fairly heavy, at least 30 pounds or more.
- The noise pattern is similar to that produced by both a gate and check valve chattering/banging.
- The source of the noise is probability within 20 of the F015A valve. (Note both the F050A and F060A are next to each other about 20 feet from the 15A)
- The occurrence of impacts does not appear correlate to the recirc pump beating frequency.
- The noise decay pattern does not provide insight to possible sources
- The impact occurrences have no distinct or repeatable pattern.
- Impacts are occurring at a rate of several per second, this is indicative of a constrained item, such as a valve
- During and after the down power, amplitudes were less, but not significantly less.
- Noise was still present after the flow change in the room.
- The noise could no longer be heard when flow was reduced to 89M lb mass / hour

Walk down Results:
As performed by Mike Reed on 3/21/2004 and documented under notifications 20182394, 5, 6, 7, 8 & 400:

[Pictures can be under M:\Shared\Technical Issues\2.Hope Creek Tech issues\HC RHR F015 Noise\Drywell walkdown pictures]
"The F060A and B show signs of limit switch failure from vibration.
The F060B hand wheel failed from vibration.
The F050A actuator fell apart.

Pictures of the KL piping are a potential source of the rattling noise we are hearing at power. It appears from the wear on the support the piping is moving about 2 inches when we are at power."

PCIG Header Piping, 1-P-KL-216SH021. At 3/22/2004 4:50 AM, Brad Tyers shook the piping. Mike Lazar listened inside the pipe chase room. A noise could be heard. It sounded more like a ping-ping-ping then the banging heard previously. Although not ruled out, it is not consideded the prime canidate for the source of the noise.

From: Horner, Jeremy D.
Sent: Saturday, March 20, 2004 11:54 PM
To: Pfizenmaier, Mark D.
Cc: McCollum, Douglas J.
Subject: RHR valve walk down

Mark,
Jeremy walked down BCHV-050A nothing seemed loose, the BCHV-122 was also SAT. However BCHV-060A had a loose hand wheel that rattled too and fro, the coaxial cable for the limit switch was loose and coming undone, finally the limit switch was severally damaged. The limit switch arm was "missing" and attachment plate will need to be rewelded. Dan Bierman also walked down the BCHV-060B and the limit switch arm is hanging.

From: Cusick, Patrick J.
Sent: Sunday, March 21, 2004 9:23 PM
To: Coslett, Kevin L.; Pfizenmaier, Mark D.; Durant, Peter
Subject: Drywell Walkdown issues
Notification 20182454 for P4B Bellows Encapsulation Sleeve loose.

The following notifications have been written, but not yet carried out:

20181917	H1BC -1BCV-111 inspection
20181918	H1BC -1BCV-117 inspection
20181920	H1BC -1-BC-V183 inspection
20181974	PIV testing

As performed by Mike Lazar on 3/22/2004: this individual had previously listened to the noise at power from both inside the pipe chase and from the loose parts monitor. As part of the walk down inside the drywell, various suspected components were subjected to agitation in attempt to recreate the noise. The approximate type of noise and closeness of the noise to the original noise are presented. This is the individual's personal opinion.

Component	Noise	Probability
P4B Bellows Encapsulation Sleeve	muffled	<1%
PCIG Header Piping	pinging	5%
F050A acutator	clunking	10%
F060A valve hand wheel	banging	85%

The F060A valve hand wheel duplicated the noise almost exactly, and I believe is/was the source of the noise.

80062466 HC-> EPU Piping Vibration Monitoring DCP
DCP 80062466 has been installed on the M-Drive. This DCP installs monitoring equipment to measure flow-induced vibration as part of the Extended Power Uprate (EPU) project for Hope Creek. This package installs cable, accelerometers on Main Steam, Recirc, and Feedwater inside the Drywell, and Main Steam, Feedwater, and Extraction Steam outside the drywell. The data will be acquired via Data Acquisition Systems consisting of a laptop (desktop), junction boxes, and signal conditioners sitting on small moveable carts. There will be one DAS in the Reactor Building, and possibly two in the turbine building. The exact locations for the accelerometer locations will be determined in the near future.

Cause(s):
PCIG Header Piping, 1-P-KL-216SH021
F050A, acutator
F060A, gate due to harmonic oscilations from the pump
P4B Bellows Encapsulation Sleeve loose

Recommendations prior to Startup:

1	Analyze affects of vibration on equipment in the drywell	Engineering	
2	Operability, address drywell components for continued operation, this may require additional pipe supports / hangers	Engineering	
3	Address broken components	Engineering	
4	Determine vibration acceptance criteria for operation	Engineering	
5	Determine locations for vibration monitoring	Engineering	
6	Install vibration monitoring equipment	Engineering	

CAUSE EVALUATION SHEET

POSSIBLE CAUSE	Existing data that supports this as the cause. / Existing data that tends to disprove this as the cause.	Data required to confirm this cause / Data required to disprove this cause	Conditions necessary to collect required data
1. Leak by on F050A check valve, which is causing water to flash to steam. **Disproved, thru time this flashing would have subsided**	Sound and vibration appeared to get stronger as you listened closer to the drywell on the line with the F015A Loose parts monitor is detecting vibrations at the jet pumps.	*Identify what the actual pressure is in the piping between the F015A and the F050A.* Equalize pressure across check valve F050A and see if rattle goes away. Once piping section pressure is equalized then noise should stop.	
	Significant amount of volume of water between the *recirc line and Check valve, which would mean that* the water temperature at the check valve is *significantly less than in, the recirc line.*		
2. Check Valve F050A valve disk is flapping. **Appears very unlikely, see Valve Eng response**	Sound and vibration appeared to get stronger as you listened closer to the drywell on the line with the F015A *Loose parts monitor* is detecting vibrations at the jet pumps. Valve Groups response "With full reactor pressure above the discs on both valves, the valves are solidly pushed into their seats and should not flutter. Therefore, it is unlikely that the noise emanating from the RHR piping outside of Penetration P4B is caused by disc movement in either H1BC -BC-HV-F050A (H1BC -1BCV-111) or H1BC -BC-HV-F122A (H1BC -1BCV-117)."	Monitor F050A valve with pumps running	Need instrumentation installed
	There would be no flow going through the valve if both sides of the valve had equalized pressure. No change in *Drywell leakage therefore there is no* leak on the F050A and no flow path to the outside of the valve that could cause valve disk to flap.		

Page __1__ of _____

POSSIBLE CAUSE	Existing data that supports this as the cause. / Existing data that tends to disprove this as the cause.	Data required to confirm this cause / Data required to disprove this cause	Conditions necessary to collect required data
3. Equalization valve HVF122A has leak by, which is causing water to flash to steam. **Disproved, thru time this flashing would have subsided**	Significant amount of volume of water between the recirc line and Check valve which would mean that the water temperature at the check valve is significantly less then in the recirc line.	Identify what the actual pressure is in the piping between the F015A and the F050A. Equalize pressure across check valve F050A and see if rattle goes away.	
	CRIDS point D7038 shows that the valve has not opened. Significant amount of volume of water between the recirc line and Check valve which would mean that the water temperature at the check valve is significantly less then in the recirc line.		
4. Valve handle is loose on manual isolation valve F060A **Most Likely Source** **When manipulated, noise is duplicated**	Noise is metallic in nature Acoustic monitoring, see results	Visually inspect F060A Valve, actuator, and handle. However BCHV-060A had a loose hand wheel that rattled too and fro, the coaxial cable for the limit switch was loose and coming undone, finally the limit switch was severally damaged. The limit switch arm was "missing" and attachment plate will need to be rewelded."	Need instrumentation installed
	Vibration in F015A line feel like the impact of something mush heavier. Loose parts monitor is detecting vibrations at the jet pumps. Small parts rattling outside of the pipe at these valves would have a low probability of sending a vibration that far.		

POSSIBLE CAUSE	**Existing data that supports this as the cause.** / **Existing data that tends to disprove this as the cause.**	**Data required to confirm this cause** / **Data required to disprove this cause**	**Conditions necessary to collect required data**
5. Valve actuator for the F050A or the F060A has loose components that are banging.	Walk down	Visually inspect F050A and F060A. "Jeremy walked down BCHV-050A nothing seemed loose, the BCHV-122 was also SAT."	Need instrumentation installed
Slight Possibility but noise generated is not the same	Loose parts monitor is detecting vibrations at the jet pumps. Small parts rattling outside of the pipe at these valves would have a low probability of sending a vibration that far.		
6. Actual loose parts in discharge piping of A Recirc Pump and Jet Pump Risers. (due to FME or failure)	Loose parts monitor is detecting vibrations at the jet pumps.	Visual Inspection Acoustic monitoring (completed)	Plant Must be in cold shutdown & head removed.
Appears very unlikely, see acoustic results	Acoustic monitoring results		
7. Pressure relief valve PSV-F055A is lifting. Possible because of leak by of F050A and F015A is causing pressure to increase in the RHR system or a failure in the valve itself.		Visually examine the F055A valve to see if it is lifting. Determine the actual pressure in RHR lines near F055A valve.	
Disproved, due to piping cool and relief valve not lifting	RHR piping feels cool to touch. Sound and vibration appeared to get stronger as you listened closer to the drywell on the line with the F015A Neither the High pressure (>380 PSI) nor the Low pressure (<47 PSI) OHA came in. The relief valves lift at >400 PSI. On 3/15/04 OS walked down valve. Valve did not appear to be lifting.		

POSSIBLE CAUSE	Existing data that supports this as the cause. Existing data that tends to disprove this as the cause.	Data required to confirm this cause Data required to disprove this cause	Conditions necessary to collect required data
8. Pressure relief valve PSV-F025A is lifting. Possible because of leak by of F050A and F015A is causing pressure to increase in the RHR system or a failure in the valve itself. **Disproved, due to piping cool and relief valve not lifting**		Visually examine the F025A valve to see if it is lifting. Determine the actual pressure in RHR lines near F025A valve.	
	RHR piping feels cool to touch. Piping next to the F017A did not have a strong vibration or sound in it. Sound and vibration appeared to get stronger as you listened closer to the drywell on the line with the F015A Neither the High pressure (>380 PSI) nor the Low pressure (<47 PSI) OHA came in. The relief valves lift at >400 PSI.		
9. Pipe Hanger or support is loose/cracked and banging from vibrations in piping. Piping vibrations could be from pressure oscillation due to Recirc flow. **Disproved by walk down**	Noise is metallic in nature. No history of pipe support or hangers breaking	Visual examinations of structure members.	
	Plant historian plots for A and B Recirc loops show no discernable change in oscillations.		
10. Recirc Flow Oscillations due to pump RPM increased and caused Item # 2 or 9. **Disproved thru testing**	Data supports that changes in Recirc pump speed directly affect the background noise heard on the line and in the N Pipe Chase Room.	Vary pump speed/flow and monitor for changes in noise. Speeds changed with no change ion noise until 91% was reached	

POSSIBLE CAUSE	Existing data that supports this as the cause. / Existing data that tends to disprove this as the cause	Data required to confirm this cause / Data required to disprove this cause	Conditions necessary to collect required data
11. PCIG Header Piping, 1-P-KL-216SH021 **Appears very unlikely,** noise generated is not the same	Found free during the drywell walk down, with signs of rubbing		Need instrumentation installed
	At 3/22/2004 4:50 AM, Brad Tyers shook the pieping. Mike Lazar listened inside the pipe chase room. A noise could be heard. It sounded more like a ping-ping-ping then the banging heard previously. Although not ruled out, it is not considederd the prime canidate for the source of the noise.		
12. P4B Bellows Encapsulation Sleeve **Appears very unlikely,** noise generated is not the same	Found loose during the drywell walk down		
	Noise stopped at 89M lb mass / hour		

Work Order Shop Papers
11/09/2004

PSEG

70037702

Order:	70037702	Common cause Recirc vibration
Order Type	NUCR	
Status	REL PCNF PRT MANC NMAT PRC SETC	
Notification	20182421	
Unit	H1	
Functional Location	H1BB	NUC BOILER & REACTOR RECIR (HOPE CREEK)
Equipment		
Assembly		
Location		
Room		
System	BB	
Priority	4	Outage
Main Work Center	E-EDC01	BARKHAMER, JOHN W.
Status	REL PCNF PRT MANC NMAT PRC SETC	
Basic Dates:	Start: 10/26/2004 Finish: 05/03/2006	Overdue:
Sfty Rltd/QA Reqd		
Sfty Class		
Mrule Code	NFF	
SEISMIC		
EQ		

Permission to Begin Work Date: Time: 00:00:00

Description of Work

Common cause Recirc vibration
03/21/2004 05:53:07 MICHAEL REED (NUMFR)
What is the actual condition?

This is an evaluation request for apparent severe vibration conditions on the recirc piping and associated piping from RHR. Numerous observations were made during the drywell walkdown that revealed damage caused by severe vibration conditions. The following notifications were generated to repair damaged parts from vibration:

20182397
20182396
21082400
20182395
20182394

20182398

How does the issue impact plant or personnel safety?

Piping appears to be experiencing an unmonitored vibration condition that is higher than the levels measure by the recirc pump proximity probes. This could lead to cyclic fatigue failure of the piping and associated components including the reactor pressure boundary.

PSEG or regulatory requirement not met?
Effective failure analysis from past evaluations on vibration.
Failure to instrument piping and structure to monitor vibration.
Failure to address long term recirc pump/piping vibration conditions. See evaluation 70032644. The evaluation failed to provide research on the extent of the vibration, conditions and instead focused on failure of individual parts.

What caused the condition?
Unknown what caused the programmatic issues.
Equipment vibration issues are known and have been a long standing issue with the recirc system at Hope Creek.

What actions, if any, have been taken to correct the condition?
Notification written. Spoke with Engineering supervision about concerns.

What should be done to fix the condition?
A common cause analysis should be performed on the above orders as well as other vibration induced repair orders to see if the recirc system vibrations are causing premature failures. This should including an evaluation that provides limits and guidelines on acceptable vibration levels on associated piping.
The recirc system and associated structure should be instrumented prior to startup to record 100% power values. This would allow for corrective action to be completed in the coming refuel outage.

Is there anyone who should be responsible for correcting the issue?

Engineering

Is a follow up assessment required?
NO
Has a post Maintenance test or Operability retest failed?
NO
Is a deficiency report required?
NO

Any other relevant information?

There is industry experience with bowing recirc pump shafts. Industry experience has shown that the bowed shafts cause vibration levels and seal failures similar to the issues that plaque Hope Creek.

Hope Creek was to change the shafts in RFO9 but the work was not performed for various reasons.

Identified on a walkdown by operations.
Should be evaluated and corrected before startup
Pictures located at:
S:\Hope Creek\OUTAGES\2004-03, March Planned Maintenance Outage\Drywell walkdown pictures

EMIS tag Number?
N/A

03/22/2004 12:07:27 THOMAS CACHAZA (NUT1C)
CRRC Note: Downgrade to SL2 with Root Cause eval per HC SM Meeting

Operation List Summary
11/09/2004

70037702

OP	Sub Op.	Work Center	Description	Start Date	Work	No	Durtn
0010		E-EDC01	Common cause Recirc vibration	03/22/2004	160.0	1	160.0
0010	0010	E-DME10	Support for Eval	03/22/2004	30.0	0	1
0010	0020	E-DMC09	Create 3D Models of Recirc Loop	03/22/2004	60.0	0	180.0
0020		E-DME00	ENTER TREND CODING	09/27/2004	1.0	1	1.0
0030		E-EDC01	OPERATING EXPERIENCE FEEDBACK	11/08/2004	4.0	1	4.0
0040		A-LSL05	Review for reportabi	04/19/2004	4.0	1	4.0

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG

		lity				
0050	E-DMC09	3D Model Support Wor k	04/27/2004	6.0	0	40.0
0060	A-QAE05	ADB Review EVAL	11/08/2004	1.0	1	1.0
0070	E-EDC01	Schedule CARB Presen tation (RC Eval)	08/19/2004	4.0	1	4.0
0080	E-EDC01	Schedule CARB Presen tation (Eff. Review)	11/08/2004	4.0	1	40.0
0100	E-EDC01	Review EPU pipe vibr ation data	11/01/2005	40.0	1	120.0
0110	E-EDC01	Acoustic Modeling Pl an to PHPC	01/04/2005	40.0	1	120.0
0120	E-PGVE07	DXG: nspect BC-HV-F0 50A Actuator	11/15/2004	4.0	1	4.0

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

0130	E-PGVE07	DXG: Create recurrin g task inspect F050A	01/11/2005	4.0	1	4.0
0132	E-PGVE03	ACD: Inspect other v alves in drywell	11/15/2004	4.0	1	4.0
0140	E-PGVE03	ACD: Remove handwhee ls (see long text)	10/22/2004	4.0	1	4.0
0145	E-EDC01	Complete effectivene ss review as determi	11/22/2004	40.0	1	80.0
0150	E-PGVE03	ACD: DCP to PHPC for Limit Switch Mod se	01/12/2005	4.0	1	4.0
0155	E-EDC01	Complete effectivene ss review as determi	04/14/2006	40.0	1	80.0
0160	E-EHN01	Trend noise in north pipe chase	10/26/2004	40.0	1	80.0
0170	E-PGVE03	ACD: Inspect BC-HV-F 060A&B and BC-HV-F05	11/15/2004	4.0	1	4.0

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

0180	E-PGVE03	Inspect valve intern als w/ radiography	11/15/2004	4.0	1	4.0
0190	E-EDC01	Obtain vendor to mon itor noise/pwr ascen	11/16/2004	40.0	1	80.0
0200	E-PGVE03	ACD: Inspect valves without failure hist	11/15/2004	4.0	1	4.0
0210	E-EDC01	Inspect small bore p iping	10/26/2004	40.0	1	80.0
0220	E-EDC01	Complete effectivene ss review as determi	11/15/2004	40.0	1	80.0
0300	E-EDC01	This operation is to prompt the Evaluato	12/06/2004	40.0	1	80.0
0310	E-EDC01	CARB Mtg Mins to RC Presentation	10/29/2004	0.0	0	0.0
0320	E-PGVE03	ACD: 3 day tracker t	11/11/2004	2.0	1	2.0

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

o confirm handwheels

Object List Summary

70037702

PSEG

Object Id	Object Description	Location	Room	SFTY RLTD/ QAR	SFTY CLASS/ QGC	SEIS	EQ	QA REQ
H1BB	NUC BOILER & REACTOR RECIR (HOPE CREEK)							
20182421	Common cause Recirc vibration							

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

70037702

Order:	70037702	Common cause Recirc vibration
Operation:	0010	Common cause Recirc vibration
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 03/22/2004	Finish: 09/30/2004
Planned Hours:	160.0	
Actual Dates:	**Start: 03/22/2004**	**Finish:09/30/2004**
Actual Hours:	**1,101.000**	**Personnel Number:** ___________
Completion Confirmation Number:		3331603

Confirmation Text: ______________________________

____

Signature: RICHARD L CUMMINS

Confirmation Text: ______________________________

____

Signature: RICHARD L CUMMINS

Confirmation Text: ______________________________

____

Signature: RICHARD L CUMMINS

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

Confirmation Text: ______________________

____

Signature: RICHARD L CUMMINS

Confirmation Text: ______________________

____

Signature: RICHARD L CUMMINS

Confirmation Text: ______________________

____

Signature: RICHARD L CUMMINS

Confirmation Text: ______________________

____

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

____

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

____

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: RICHARD L CUMMINS

Confirmation Text:

Signature: RICHARD L CUMMINS

Confirmation Text:

support root cause team

Signature: MARK A BERGMAN

Confirmation Text:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

support root cause team

Signature: MARK A BERGMAN

Confirmation Text:

support root cause team

Signature: MARK A BERGMAN

Confirmation Text:

support root cause team

Signature: MARK A BERGMAN

Confirmation Text:

Signature: RICHARD L CUMMINS

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

PSEG Public Service Electric and Gas Company

Signature: JOHN W. BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Work center manager, Mehdi Tadjalli, app

Work center manager, Mehdi Tadjalli, approved extending the completion of the common cause analysis to May 21, 2003. This occurred on 4/20/04 at 1430. This extension is to accommodate the collection of recirculation system vibration data during startup, completion of metallurgical analysis, and complete failure analysis. The risk of extending this evaluation is negligible noting that the basis for safe plant restart was developed in approved engineering evaluation H-1-BB-CEE-1850 and was SORC reviewed.

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

Signature: ALAN A JOHNSON

Confirmation Text:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

PSE&G Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

PSEG Public Service Electric and Gas Company

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: JOHN W. BARKHAMER

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

PSEG Public Service Electric and Gas Company

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________________

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

Signature: ALAN A JOHNSON

Confirmation Text: ______________________________

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: ALAN A JOHNSON

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

Signature: JOHN W BARKHAMER

Confirmation Text: ______

PSEG Public Service Electric and Gas Company

Signature: ALAN A JOHNSON

Confirmation Text: __________

Signature: ALAN A JOHNSON

Confirmation Text: __________

Signature: ALAN A JOHNSON

Confirmation Text: __________

Signature: ALAN A JOHNSON

Confirmation Text: __________

Signature: ALAN A JOHNSON

Confirmation Text: __________

Root Cause Eval (See Long Text)
Root Cause Eval (See Long Text)

Problem Statement

PSEG Public Service Electric and Gas Company

During the Hope Creek maintenance outage in the spring of 2004 several components were found degraded or failed. The failures were initially attributed to vibration induced fatigue. Engineering evaluationH-1-BB-CEE-1830 was prepared to assess the safety significance of the condition and the impact on restart. The conclusion of the engineering evaluation was that the safety significance of the identified failures was low and the plant could be safely operated if the recommendations in the evaluation were completed. A vibration monitoring program was implemented during plant restart to determine the nature and magnitude of the vibration to ensure the plant was not experiencing a new source of vibration. A root cause evaluation was started to determine the actual cause of the failures and to recommend correctiveactions to prevent reoccurrence.

The root cause evaluation report is contained in engineering evaluation H-1-BB-CEE-1862 and contains a detailed discussion of the attributes required by NC.CA-TM.ZZ-0004 Root Cause Evaluation Template. Below is the Executive Summary, Table of Contents, and corrective actions from the report.

Executive Summary

On March 13, 2004 an unusual banging noise, reportedly coming from inside containment, was heard by Hope Creek plant personnel entering the north pipe chase. When the plant was subsequently shutdown, containment walkdowns revealed a number of degraded conditions inside containment, primarily on the RHR return lines that connect to the recirculation piping main loops. The degraded conditions were thought to have resulted from vibration of the recirculation and RHR piping during operation. This common cause analysis report summarizes results of investigations into the cause of the vibration and the resulting degradation, and the noise heard in the pipe chase.

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

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

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

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

The effect of this vibration has been to cause degradation of components in the RHR piping inside containment; specifically, hardware connected to certain RHR valves. This report also explores the individual degraded conditions that stem from this common cause.

The report finds that the common cause of the current and past degradation observed at the plant results from equipment being subjected to pump-induced pressure pulsations at frequencies at or near equipment structural resonances. This results in vibratory loads on the equipment which over time cause the equipment to degrade due to high cycle wear, fretting or fatigue. The fact that the installed plant equipment has structural resonances at or near the expected pump pulsation frequency ranges indicates that the original plant design did not guard against this possibility. It is noted that due to the variable speed operation of the recirculation pumps, and the wide range of speeds at which they operate, makes it difficult to design equipment with natural frequencies that will not be excited by the wide range of expected pulsation frequencies.
An earlier effort to determine the source of the noise heard in March 2004 determined that the noise originated either from a detached air piston cylinder associated with a check valve in the RHR piping inside containment, or possibly from a loose handwheel on an adjacent block valve. Both of these conditions were fixed prior to restarting the plant in April 2004. However, in May 2004 the noise returned. Accordingly, at this time the cause of the noise has not been positively ascertained. The report investigates possible causes and provides recommendations for validating the actual cause.

Table of Contents

Recommended Corrective Actions
Summarized from Section 8.0 of the report

Report Section 6.1 Recirculation and RHR piping vibration

Condition: The accelerations generally increase at vane passing frequencies starting about 120Hz and continue to increase up until the highest vane passing frequency monitored.

Remedial Corrective Action:
Review pipe vibration data when the pumps operate above 1500 rpm. This data collection will be performed as a part of the EPU project as a part of DCP 80062466.
Operation 100 CRCA Owner E-EDC-01 Due Date is based on completion of data acquisition during cycle 13. Due Date 12/01/05.

Condition: Monitoring data indicates evidence of potential acoustic resonance.

Remedial Corrective Action: Acoustical modeling of the system should be done to determine if planned changes to system operating conditions as a result of the EPU may result in unfavorable changes to the system acoustical resonance.
Present Acoustical Modeling plan to PHPC for approval.
Operation 110 CRCA Owner E-EDC01 Due Date 02/01/05

Report Section 6.2
Condition : BCHV-F050A actuator damage

Remedial Corrective Action:

Inspect the BC-HV-F050A actuator for signs of looseness. If looseness is detected disassemble the actuator and inspect the cap screw and threads for signs of degradation. If signs of degradation are detected prepare a DCP to modify the actuator as dictated by the as found condition.
Operation 120 CRCA Owner E-PGVE00 Due Date 11/12/04

Remedial Corrective Action:
Create a recurring task to inspect the F050A in subsequent outages until a determination is made that the condition does not worsen over time.
Operation 130 CRCA Owner E-PGVE00 Due Date 11/15/04

Remedial Corrective Action:
Inspect other valves in the drywell during RF 12 that have the same type of actuator:
H1BC BC-HV-F050B
H1BC BC-HV-F041A/B/C/D
H1BC BC-HV-F006A/B
Operation 132 CRCA Owner E-PGVE00 Due Date 11/15/04

Report Section 6.3
Condition: Detachment of hand wheel from valve BCHV-F060B

CAPR Corrective Action:
Develop an administrative control mechanism to remove the hand wheels from the H1BC BC-HV-F060A&B and H1BC BC-HV-F077 prior to operation each cycle. If hand wheels can not be removed create a PM to inspect every outage and replace as necessary.
Operation 140 CAPR E-PGVE00 Due Date 10/29/04
Effectiveness Review:
If the hand wheels are removed and administratively controlled then, an effectiveness review is not required. If a PM is created to inspect every outage and replace as necessary the effectiveness review will ensure the PM has defined acceptance criteria and is scheduled for every refueling outage.
Operation 145 VERF Owner E-EPGVE00 Due Date 10/29/04

Report Section 6.4
Condition: Limit switch failures on valves BCHV-F060A&B
CAPR Corrective Action:
Present a DCP to PHPC to modify the limit switch mounting. As a part of the DCP it will be necessary to accurately determine the natural frequency of the stem protector assembly and stem finger by static ring test during RF12, OR prepare an accurate finite element model of the valve top works including the stem protector assembly. Develop a DCP to modify the valve top works and stem protector assembly to ensure the parts can resist the measured dynamic responses. Include sufficient post mod testing to ensure goals are met.
Status: DCP 80072763 approved by PHPC. DCP issue is scheduled for 10/29/04
Operation 150 CAPR Owner E-PGVE00 Due Date 11/15/04

Effectiveness Review:
After DCP implementation the limit switches should be inspected any signs of vibration degradation during R13.
Operation VERF 155 Owner E-EDC01 Due Date 05/15/06

Report Section 6.5

Condition: Audible noise in the north pipe chase

Remedial Corrective Action:
Trend the audible noise in the north pipe chase, by periodically observing the noise and recording key data when a change is noticed. See Report Section 6.5 for key data.
Operation CRCA160 Owner E-EHN01 Due Date 11/15/04

Remedial Corrective Action:
Inspect the H1BC BC-HV-F060A&B and H1BC BC-HV-F050A actuator internals for signs of wear or loose parts. The inspection should be performed when the gear box cover plate is replaced by DCP 80072763.
Operation CRCA170 Owner E-PGVE-00 Due Date 11/15/04

Remedial Corrective Action:
Inspect the H1BC BC-HV-F060A and H1BC BC-HV-F050A valve internals by obtaining a radiograph of each valve. If evidence of loose parts, open and inspect each valve.
Operation CRCA180 Owner E-PGVE-00 Due Date 11/15/04

Remedial Corrective Action:
Perform monitoring of the audible noise in the north pipe chase during power ascension. Obtain the services of Framatome or VibrAlign to determine if the noise is detectable on the vibration monitoring data acquisition system.
Operation CRCA 190 Owner E-EDC01 Due Date 10/28/04

Report Section 7.1
Extent of Condition

Remedial Corrective Action:
Visually inspect the following valves that do not have a history of part failures but are subject to the same vibrations:
H1BB BB-HV-F023A&B
H1BB BB-HV-F031A&B
H1BC BC-HV-F009
H1BC BC-HV-F008
H1BC BC-HV-F015A&B
Operation CRCA200 Owner E-PGVE-00 Due Date 11/15/04

Remedial Corrective Action:

PSE&G Public Service Electric and Gas Company

Visually inspect attached small bore instrumentation piping attached the recirculation pumps and motors for signs of vibration induced degradation and ensure supports and configuration is accordance with design documents.
Operation 210 Owner E-EDC01 Due Date 11/15/04

Verification of Effectiveness Reviews
Verify all effectiveness are complete.
Operation 220 VERF Owner E-EDC01 Due Date 06/01/06

Feedback to Initiator
Operation 300 VERF Owner E-EDC01 Due Date 06/01/06

Signature: JOHN W BARKHAMER

Confirmation Text:

Approved - see long text
Approved - see long text

Confirmation entered by: J. C. Bisti for M. Tadjalli X1962
Manager - Design Engineering

Signature: Joseph C Bisti

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

PSEG Public Service Electric and Gas Company

Signature: SHELLY F KUGLER

Confirmation Text:

Signature: SHELLY F KUGLER

Confirmation Text:

Signature: SHELLY F KUGLER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

Signature: JOHN W BARKHAMER

Confirmation Text:

PSEG Public Service Electric and Gas Company

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

____

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

____

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________

____

Signature: SHELLY F KUGLER

Confirmation Text: ______________________

____

Signature: SHELLY F KUGLER

Confirmation Text: ______________________

____

Signature: SHELLY F KUGLER

Description of Work:

Common cause Recirc vibration

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Perform a Root Cause Evaluation using guidance provided in NC.WM-AP.ZZ-0002(Q) Attachment 2.

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0010 - 0010	Support for Eval
Work center:	E-DME10	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	0	
Scheduled Dates:	Start: 03/22/2004	Finish: 09/30/2004
Planned Hours:	30.0	
Actual Dates:	Start: 03/26/2004	Finish:06/02/2004
Actual Hours:	7.500	Personnel Number: ______
Completion Confirmation Number:		3343700

Confirmation Text: ______

______

Signature: LISA H HITCHNER

Confirmation Text: ______

______

Signature: LISA H HITCHNER

Confirmation Text: ______

______

Signature: LISA H HITCHNER

Confirmation Text: ______

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: LISA H HITCHNER

Confirmation Text:

Signature: LISA H HITCHNER

Confirmation Text:

Supported CRCA for Root Cause Team Commo

Supported CRCA for Root Cause Team Common cause Recirc vibration

Signature: LISA H HITCHNER

Description of Work:

SAFETY: The Only C.H.O.I.C.E.

Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0010 - 0020	Create 3D Models of Recirc Loop
Work center:	E-DMC09	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	0	
Scheduled Dates:	Start: 03/22/2004	Finish: 09/30/2004
Planned Hours:	60.0	
Actual Dates:	**Start: 03/26/2004**	**Finish:04/23/2004**
Actual Hours:	**61.000**	**Personnel Number:** ___________
Completion Confirmation Number:		**3351799**

Confirmation Text: ______________________________

____

Signature: Deborah Rambo

Confirmation Text: ______________________________

____

Signature: Deborah Rambo

Confirmation Text: ______________________________

____

Signature: Deborah Rambo

Confirmation Text: ______________________________

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: Deborah Rambo

Confirmation Text: ______________________

Signature: Deborah Rambo

Confirmation Text: ______________________

Signature: Deborah Rambo

Confirmation Text: ______________________

Signature: Deborah Rambo

Confirmation Text: ______________________

Signature: Deborah Rambo

Confirmation Text: ______________________

Signature: Deborah Rambo

Confirmation Text: ______________________

PSEG Public Service Electric and Gas Company

Signature: Deborah Rambo

Confirmation Text:

Signature: Deborah Rambo

Confirmation Text:

Closed to avoid PM01 issue.

Signature: ALAN A JOHNSON

Description of Work:

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0020	ENTER TREND CODING
Work center:	E-DME00	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 09/27/2004	**Finish:** 09/27/2004
Planned Hours:	1.0	
Actual Dates:	**Start: 09/27/2004**	**Finish:09/27/2004**
Actual Hours:	**0.000**	**Personnel Number:** ________
Completion Confirmation Number:		3331604

Confirmation Text: ______________________________

trend code complete

____

Signature: JOHN M HILDITCH

Description of Work:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0030	OPERATING EXPERIENCE FEEDBACK
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/08/2004	**Finish:** 11/08/2004
Planned Hours:	4.0	
Actual Dates:	**Start: 04/22/2004**	**Finish:10/07/2004**
Actual Hours:	**0.000**	**Personnel Number:** ________
Completion Confirmation Number:		3331605

Confirmation Text: ____________________

Due date extended to 5/31/04 to correspo
Due date extended to 5/31/04 to correspond to the extension of the evaluation.

Signature: ALAN A JOHNSON

Confirmation Text: ____________________

Due Date Extended to 10/8/04
Due Date Extended to 10/8/04
Due date extended with OE Program Manager(NUKCM) concurrence.NUJAB 10/23/04

Signature: JOHN W BARKHAMER

Confirmation Text: ____________________

Due Date Extended to 10/22/2004
Due Date Extended to 10/22/2004
with concurrance from eval manager supervisor

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Signature: JOHN W BARKHAMER

Description of Work:

OPERATING EXPERIENCE FEEDBACK

This event potentially meets INPO's criteria for posting a report to Nuclear Network.

- The INPO Goal is to issue report in 50 days
- Extension beyond 30 days from event could prevent issuing report in 50 days
- Any questions call Ken Myers x-2328.
- Format for OE is available on the Operating Experience Web page thru the NBU home page
- Send draft via e-mail to Ken Myers.

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0040	Review for reportability
Work center:	A-LSL05	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 04/19/2004	Finish: 05/05/2004
Planned Hours:	4.0	
Actual Dates:	Start: 04/19/2004	Finish:05/05/2004
Actual Hours:	13.000	Personnel Number: ________
Completion Confirmation Number:		3380707

Confirmation Text: ____

____

Signature: Michael G Mosier

Confirmation Text: ____

____

Signature: Michael G Mosier

Confirmation Text: ____

____

Signature: Michael G Mosier

Confirmation Text: ____

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Signature: Michael G Mosier

Confirmation Text:

Signature: Michael G Mosier

Confirmation Text:

Signature: Michael G Mosier

Confirmation Text:

see long text
see long text

This was evaluated under 10CFR50.72(a)(2)(ii) and 50.73(a)(2)(ii), an event or condition that resulted in a degraded or unanalyzed condition.

The observed vibration levels are well within the GE acceptance criteria. An initial review of the data supports the engineering evaluation (H-1-BB-CEE-1830)conclusion that the recir and rhr systems in the drywell are experiencing vibration levels consistent with what they have experienced in the past and the failures discovered during the April maintenance outage do not appear to be the result of new or severe vibration. The data will be used in the ongoing cause evaluation of the failures in an effort to increase equipment reliability.

This is based upon the engineering evaluation of vibration data from the drywell vibration monitoring program. E-mail from S. Kugler to M. Tadjalli on 5/2/2004.

Therefore, based upon the above this is not reportable.
NUM1M 5-5-2004.

Signature: Michael G Mosier

PSE&G Public Service Electric and Gas Company

Confirmation Text:

concur

Signature: John C Nagle

Confirmation Text:

Signature: Michael G Mosier

Confirmation Text:

Signature: Michael G Mosier

Confirmation Text:

Signature: Michael G Mosier

Description of Work:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration	
Operation:	0050	3D Model Support Work	
Work center:	E-DMC09	NNUC	
Status:	REL PCNF PRT MANC NMAT		
Number of People:	0		
Scheduled Dates:	Start: 04/27/2004	Finish: 06/08/2004	
Planned Hours:	6.0		
Actual Dates:	Start: 04/27/2004	Finish:06/08/2004	
Actual Hours:	6.000	Personnel Number:	________
Completion Confirmation Number:		3408791	

Confirmation Text: ______________________

____

Signature: Deborah Rambo

Confirmation Text: ______________________

____

Signature: Deborah Rambo

Confirmation Text: ______________________

____

Signature: Deborah Rambo

Description of Work:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

SAFETY: The Only C.H.O.I.C.E.

Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0060	ADB Review EVAL
Work center:	A-QAE05	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/08/2004	**Finish:** 11/08/2004
Planned Hours:	1.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3501579

Confirmation Text: ______________________________

____

Signature: ______________________________

Description of Work:

ADB Review EVAL

10/05/04: NC.WM-AP.ZZ-0002(Q), Section 5.4.4.A, requires that an EVAL that is a Root Cause or Apparent Cause Evaluation be presented to CARB. Operation 0070 tracks the CARB presentation with a current due date of 10/15/04. This EVAL due date is being moved to 11/19/04. Andy du Bouchet, x3084.

09/02/04: Due date moved to 10/15/04 to follow due date of 09/10/04 for Operation 0010. Andy du Bouchet, x3084

06/23/04: Due date moved to 08/31/04 to follow due date of 07/18/04 for Operation 0010. NUAVD, x3084

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

08/09/04: Due date moved to 09/24/04 to follow due date of 08/20/04 for Operation 0010. Andy du Bouchet, x3084

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0070	Schedule CARB Presentation (RC Eval)
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 08/19/2004	**Finish:** 10/14/2004
Planned Hours:	4.0	
Actual Dates:	**Start: 08/19/2004**	**Finish:10/14/2004**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3581574

Confirmation Text: ____________________

Date moved to reflect new CARB presentat
Date moved to reflect new CARB presentation date.

Signature: KIMBERLY A HILL

Confirmation Text: ____________________

See long text
See long text
CARB was scheduled and attended on September 28, 2004. Root cause evaluation report which is contained in engineering evaluation H-1-BB-CEE-1862 was presented to the board and accepted. No further actions required for this CARB.

Signature: SHELLY F KUGLER

Description of Work:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration	
Operation:	0080	Schedule CARB Presentation (Eff. Review)	
Work center:	E-EDC01	NNUC	
Status:	REL PCNF PRT MANC NMAT		
Number of People:	1		
Scheduled Dates:	Start: 11/08/2004	Finish: 11/16/2004	
Planned Hours:	4.0		
Actual Dates:	Start:	Finish:	
Actual Hours:	0.000	Personnel Number:	________
Completion Confirmation Number:		3581575	

Confirmation Text: ____

____

Signature: ________________________

Description of Work:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0100	Review EPU pipe vibration data
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/01/2005	**Finish:** 11/30/2005
Planned Hours:	40.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728703

Confirmation Text: ______________________________________

____

Signature: ____________________________

Description of Work:

Review EPU pipe vibration data
Review pipe vibration data when the pumps operate above 1500 rpm. This data collection will be performed as a part of the EPU project as a part of DCP 80062466.
Operation 100 CRCA Owner - E-EDC-01 Due Date is based on completion of data acquisition during cycle 13.Due Date 12/01/05.

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0110	Acoustic Modeling Plan to PHPC
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 01/04/2005	Finish: 01/31/2005
Planned Hours:	40.0	
Actual Dates:	Start:	Finish:
Actual Hours:	0.000	Personnel Number: ________
Completion Confirmation Number:		3728732

Confirmation Text: ____

____

Signature: ______________________________

Description of Work:

Acoustic Modeling Plan to PHPC
Acoustical modeling of the system should be done to determine if planned changes to system operating conditions as a result of the EPU may result in unfavorable changes to the system acoustical resonance.
Present Acoustical Modeling plan to PHPC for approval.
Operation 110 CRCA Owner E-EDC01 Due Date 02/01/05

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0120	DXG: nspect BC-HV-F050A Actuator
Work center:	E-PGVE07	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/15/2004	**Finish:** 11/15/2004
Planned Hours:	4.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728733

Confirmation Text: ______________________________

____

Signature: ______________________________

Description of Work:

DXG: nspect BC-HV-F050A Actuator
Inspect the BC-HV-F050A actuator for signs of looseness. If looseness is detected disassemble the actuator and inspect the cap screw and threads for signs of degradation. If signs of degradation are detected prepare a DCP to modify the actuator as dictated by the as found condition.
Operation 120 CRCA Owner E-PGVE00 Due Date 11/12/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0130	DXG: Create recurring task inspect F050A
Work center:	E-PGVE07	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 01/11/2005	**Finish:** 01/11/2005
Planned Hours:	4.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728734

Confirmation Text: ______________________________

____

Signature: ______________________

Description of Work:

DXG: Create recurring task inspect F050A
Create a recurring task to inspect the F050A in subsequent outages until a determination is made that the condition does not worsen over time.
Operation 130 CRCA Owner E-PGVE00 Due Date After RF12.

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0132	ACD: Inspect other valves in drywell
Work center:	E-PGVE03	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/15/2004	**Finish:** 11/15/2004
Planned Hours:	4.0	
Actual Dates:	**Start: 11/09/2004**	**Finish:11/09/2004**
Actual Hours:	**0.000**	**Personnel Number:** ________
Completion Confirmation Number:		3728735

Confirmation Text: ____________________

Completed Valve Inspections - SAT
Completed Valve Inspections - SAT

No visual damage was found upon inspecting the following valve assemblies:

1BC-HV-F050A, 1BC-HV-F050B, 1BC-HV-F041A, 1BC-HV-F041B, 1BC-HV-F041C, 1BC-HV-F041D, 1BC-HV-F006A and 1BC-HV-F006B

____

Signature: MARK A SMITH

Description of Work:

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

ACD: Inspect other valves in drywell
Inspect other valves in the drywell during RF 12 that have the same type of actuator:
H1BC -BC-HV-FO50B
H1BC -BC-HV-F041A/B/C/D
H1BC -BC-HV-F006A/B
Operation 132 CRCA Owner E-PGVEOO Due Date 11/15/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0140	ACD: Remove handwheels (see long text)
Work center:	E-PGVE03	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 10/22/2004	**Finish:** 10/30/2004
Planned Hours:	4.0	
Actual Dates:	**Start: 10/22/2004**	**Finish:10/30/2004**
Actual Hours:	**4.000**	**Personnel Number:** ______
Completion Confirmation Number:		3728736

Confirmation Text: ______

Signature: AMBER C DOVE

Confirmation Text: ______

Disptn by ACD, entered into SAP by DJM-

Disptn by ACD, entered into SAP by DJM- Operations has agreed to remove the handwheels. Handwheels to be removed during RF12. Operation 0320 created as verf to verify work is done during RF12.

Signature: DOUGLAS J MC COLLUM

Confirmation Text: ______

Supervisor review and approval by DJM

Signature: DOUGLAS J MC COLLUM

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Description of Work:

ACD: Remove handwheels (see long text)
Develop an administrative control mechanism to remove the hand wheels from the H1BC -BC-HV-F060A&B and H1BC -BC-HV-F077 prior to operation each cycle. If hand wheels can not be removed create a PM to inspect every outage and replace as necessary.
Operation 140 CAPR E-PGVE00 Due Date 10/29/04

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0145	Complete effectiveness review as determi
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/22/2004	**Finish:** 12/01/2004
Planned Hours:	40.0	
Actual Dates:	**Start: 10/15/2004**	**Finish:10/27/2004**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728874

Confirmation Text: ________________________________

Moved Date to 12/03/04
Moved Date to 12/03/04
The due date was extended to 12/03/04 since the original date was inadvertently assigned the same date as the corrective action.

____

Signature: JOHN W BARKHAMER

Description of Work:

Complete effectiveness review as determined in Root Cause Evaluation.
If the hand wheels are removed and administratively controlled then, an effectiveness review is not required. If a PM is created to inspect every outage and replace as necessary the effectiveness review will ensure the PM has defined acceptance criteria and is scheduled for every refueling outage.
Operation 145 VERF Owner - E-EPGVE00 Due Date 10/29/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0150	ACD: DCP to PHPC for Limit Switch Mod se
Work center:	E-PGVE03	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 01/12/2005	Finish: 01/12/2005
Planned Hours:	4.0	
Actual Dates:	Start:	Finish:
Actual Hours:	0.000	Personnel Number: ___________
Completion Confirmation Number:		3728875

Confirmation Text: ____

____

Signature: ______________________________

Description of Work:

ACD: DCP to PHPC for Limit Switch Mod seetext
Present a DCP to PHPC to modify the limit switch mounting. As a part of the DCP it will be necessary to accurately determine the natural frequency of the stem protector assembly and stem finger by static ring test during RF12, OR prepare an accurate finite element model of the valve top works including the stem protector assembly. Develop a DCP to modify the valve top works and stem protector assembly to ensure the parts can resist the measured dynamic responses. Include sufficient post mod testing to ensure goals are met.
Status: DCP 80072763 approved by PHPC. DCP issue is scheduled for 10/29/04
Operation 150 CAPR Owner E-PGVE00 Due Date 11/15/04- Post RF12 due date.
PHPC presentation made for RF12 scope.Post RF12 PHPC to reflect start-up testing-Doug McCollum

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0155	Complete effectiveness review as determi
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 04/14/2006	**Finish:** 05/03/2006
Planned Hours:	40.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728876

Confirmation Text: ______________________________________

____

Signature: ______________________________

Description of Work:

Complete effectiveness review as determined in Root Cause Evaluation.
After DCP implementation the limit switches should be inspected any signs of vibration degradation during R13.

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0160	Trend noise in north pipe chase
Work center:	E-EHN01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 10/26/2004	Finish: 11/15/2004
Planned Hours:	40.0	
Actual Dates:	Start:	Finish:
Actual Hours:	0.000	Personnel Number: __________
Completion Confirmation Number:		3728877

Confirmation Text: ____

____

Signature: ______________________________

Description of Work:

Trend noise in north pipe chase
Trend the audible noise in the north pipe chase, by periodically observing the noise and recording key data when a change is noticed. See Report Section 6.5 for key data.
Operation CRCA160 Owner E-EHN01 Due Date 11/15/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation: BC-HV-F05	0170	ACD: Inspect BC-HV-F060A&B and
Work center:	E-PGVE03	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/15/2004	**Finish:** 11/15/2004
Planned Hours:	4.0	
Actual Dates:	**Start: 10/21/2004**	**Finish:10/21/2004**
Actual Hours:	**4.000**	**Personnel Number:** ________
Completion Confirmation Number:		3728878

Confirmation Text: ______________________________

____

Signature: AMBER C DOVE

Description of Work:

ACD: Inspect BC-HV-F060A&B and BC-HV-F050A
Inspect the H1BC -BC-HV-F060A&B and H1BC -BC-HV-F050A actuator internals for signs of wear or loose parts. The inspection should be performed when the gear box cover plate is replaced by DCP 80072763.
Operation CRCA170 Owner E-PGVE-00 Due Date 11/15/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0180	Inspect valve internals w/ radiography
Work center:	E-PGVE03	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/15/2004	**Finish:** 11/15/2004
Planned Hours:	4.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728879

Confirmation Text: ____

____

Signature: ______________________________

Description of Work:

Inspect valve internals w/ radiography
Inspect the H1BC -BC-HV-F060A and H1BC -BC-HV-F050A valve internals by obtaining a radiograph of each valve. If evidence of loose parts, open and inspect each valve.
Operation CRCA180 Owner E-PGVE-00 Due Date 11/15/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0190	Obtain vendor to monitor noise/pwr ascen
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 11/16/2004	**Finish:** 11/16/2004
Planned Hours:	40.0	
Actual Dates:	**Start: 10/08/2004**	**Finish:10/29/2004**
Actual Hours:	**0.000**	**Personnel Number:** ________
Completion Confirmation Number:		3728880

Confirmation Text: ______________________________

See long Text - NUJAB 10/27/2004
See long Text - NUJAB 10/27/2004
It has been determined that VibrAlign will be be used to monitor the noise in the north pipe chase. Adequate funds exist in PO 4500246510 Line 10.

____

Signature: JOHN W BARKHAMER

Confirmation Text: ______________________________

Date Changed to 01/29/2005-See Long Text
Date Changed to 01/29/2005-See Long Text
The operation describes 2 related activities that need to be completed. 1) Obtain a vendor to perfrom the monitoring, and 2)Perform the monitoring during power ascension. The original due date selected was 10/28/2004 which is long before power ascension will occur, and therefore cannot be met. There is not a risk to plant safety or reliability associated with the date change since the original intent was to perform the activity during power ascension and that will not change. The situation was discussed with CARB member Director of Engineering and the due date was changed to 01/29/2005. An email was sent to the CARB Chairman.

____

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Signature: JOHN W BARKHAMER

Description of Work:

Obtain vendor to monitor noise/pwr ascen
Perform monitoring of the audible noise in the north pipe chase during power ascension. Obtain the services of Framatome or VibrAlign to determine if the noise is detectable on the vibration monitoring data acquisition system.
Operation CRCA 190 Owner E-EDC01 Due Date 10/28/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order: 70037702 Common cause Recirc vibration

Operation: 0200 ACD: Inspect valves without failure hist

Work center: E-PGVE03 NNUC

Status: REL PCNF PRT MANC NMAT

Number of People: 1

Scheduled Dates: Start: 11/15/2004 Finish: 11/15/2004

Planned Hours: 4.0

Actual Dates: Start: 11/09/2004 Finish:11/09/2004

Actual Hours: 0.000 Personnel Number: __________

Completion Confirmation Number: 3728881

Confirmation Text: ______________________________

Completed Valve Inspections - SAT
Completed Valve Inspections - SAT

No visual damage was found upon inspecting the following valve assemblies:

1BB-HV-F023A, 1BB-HV-F023B, 1BB-HV-F031A, 1BB-HV-F031B, 1BC-HV-F008, 1BC-HV-F009, 1BC-HV-F015A and 1BC-HV-F015B

____

Signature: MARK A SMITH

Description of Work:

ACD: Inspect valves without failure history
Visually inspect the following valves that do not have a history of part failures but are subject to the same vibrations:
H1BB -BB-HV-F023A&B
H1BB -BB-HV-F031A&B
H1BC -BC-HV-F009
H1BC -BC-HV-F008

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

H1BC -BC-HV-F015A&B
Operation CRCA200 Owner E-PGVE-00 Due Date 11/15/04

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0210	Inspect small bore piping
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 10/26/2004	Finish: 11/12/2004
Planned Hours:	40.0	
Actual Dates:	Start:	Finish:
Actual Hours:	0.000	Personnel Number: ________
Completion Confirmation Number:		3728882

Confirmation Text: ____________________________________

____

Signature: ____________________________

Description of Work:

Inspect small bore piping
Visually inspect attached small bore instrumentation piping attached the recirculation pumps and motors for signs of vibration induced degradation and ensure supports and configuration is accordance with design documents.
Operation 210 Owner E-EDC01 Due Date 11/15/04

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSEG Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0220	Complete effectiveness review as determi
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 11/15/2004	Finish: 12/06/2004
Planned Hours:	40.0	
Actual Dates:	Start:	Finish:
Actual Hours:	0.000	Personnel Number: ________
Completion Confirmation Number:		3728883

Confirmation Text: ______________________________________

____

Signature: ______________________________

Description of Work:

Complete effectiveness review as determined in Root Cause Evaluation. Confirm completion of all effectiveness reviews.

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0300	This operation is to prompt the Evaluato
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	**Start:** 12/06/2004	**Finish:** 12/23/2004
Planned Hours:	40.0	
Actual Dates:	**Start:**	**Finish:**
Actual Hours:	0.000	**Personnel Number:** ________
Completion Confirmation Number:		3728884

Confirmation Text: ____

____

Signature: ______________________________

Description of Work:

This operation is to prompt the Evaluator to feedback to the Notification Initiator that the actions have been completed to address their identified issue.

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation:	0310	CARB Mtg Mins to RC Presentation
Work center:	E-EDC01	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	0	
Scheduled Dates:	**Start:** 10/29/2004	**Finish:** 10/29/2004
Planned Hours:	0.0	
Actual Dates:	**Start: 10/29/2004**	**Finish:10/29/2004**
Actual Hours:	**0.000**	**Personnel Number:** ________
Completion Confirmation Number:		3816295

Confirmation Text: ____________________

CARB Meeting Minutes
CARB Meeting Minutes
Root Cause and Apparent Cause Evaluations
September 30, 2004

Topic/Title: #Common Cause on Hope Creek RHR Piping Vibration

Order No:#70037702

Chairman: #Mike Brothers # VP # Site Operations
##Carl Fricker # Plant Manager - Salem
Larry Wagner # Plant Manager # Station Support
##Jim Hutton # Plant Manager # Hope Creek
##Pat Walsh # Director - Engineering
##Nick Conicella # Training Manager
##Jim Clancy # Manager # Rad Pro/Chemistry
##Patricia Steinhauer # Station Support - Manager
##A. Carolyn Taylor # CARB Advisor

Presenter(s):#Joe Bisti, Alan Johnson, Shelly Kugler, and John Barkhammer.

Summary:

On March 13, 2004 an unusual banging noise, reportedly coming from inside containment, was heard by Hope Creek plant personnel entering the north pipe chase. When the plant was subsequently shutdown, containment walkdowns revealed a number of degraded conditions inside containment, primarily on the RHR return lines that connect to the recirculation piping main loops. The degraded conditions were thought to have resulted from vibration of the recirculation and RHR piping during operation. This common cause analysis report summarizes results of investigations into the cause of the vibration and the resulting degradation, and the noise heard in the pipe chase.

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

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

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

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

The effect of this vibration has been to cause degradation of components in the RHR piping inside containment; specifically, hardware connected to certain RHR valves. This report also explores the individual degraded conditions that stem from this common cause.

The report finds that the common cause of the current and past degradation observed at the plant results from equipment being subjected to pump-induced pressure pulsations at frequencies at or near equipment structural resonances. This results in vibratory loads on the equipment which over time cause the equipment to degrade due to high cycle wear, fretting or fatigue. The fact that the installed plant equipment has structural resonances at or near the expected pump pulsation frequency ranges indicates that the original plant design did not guard against this possibility. It is noted that due to the variable speed operation of the recirculation pumps, and the wide range of speeds at which they

PSE&G Public Service Electric and Gas Company

operate, makes it difficult to design equipment with natural frequencies that will not be excited by the wide range of expected pulsation frequencies.

An earlier effort to determine the source of the noise heard in March 2004 determined that the noise originated either from a detached air piston cylinder associated with a check valve in the RHR piping inside containment, or possibly from a loose handwheel on an adjacent block valve. Both of these conditions were fixed prior to restarting the plant in April 2004. However, in May 2004 the noise returned. Accordingly, at this time the cause of the noise has not been positively ascertained. The report investigates possible causes and provides recommendations for validating the actual cause.

CARB approved this evaluation without comments.

Signature: LAWRENCE M WAGNER

Description of Work:

Operation Key Info
11/09/2004

PSE&G Public Service Electric and Gas Company

Order:	70037702	Common cause Recirc vibration
Operation: handwheels	0320	ACD: 3 day tracker to confirm
Work center:	E-PGVE03	NNUC
Status:	REL PCNF PRT MANC NMAT	
Number of People:	1	
Scheduled Dates:	Start: 11/11/2004	Finish: 11/11/2004
Planned Hours:	2.0	
Actual Dates:	Start:	Finish:
Actual Hours:	0.000	Personnel Number: ___________
Completion Confirmation Number:		3815634

Confirmation Text: ____

____

Signature: ______________________________

Description of Work:

ACD: 3 day tracker to confirm handwheels are removed. To be updated every 3 days until handwheels are removed in field.

SAFETY: The Only C.H.O.I.C.E.
Commitment Help Oversight Involvement Communication Empowerment