U.S. NUCLEAR REGULATORY COMMISSION
REGION I

Report No. 50-219/88-24

Docket No. 50-219

License No. DPR-16

Licensee: GPU Nuclear Corporation
P.O. Box 388
Forked River, New Jersey 08731

Facility Name: Oyster Creek Nuclear Generating Station

Inspection At: Forked River, New Jersey

Inspection Conducted: July 15, 1988 and July 18 through August 12, 1988

Inspectors: Herbert J. Kaplan — 9/8/88
Herbert J. Kaplan, Senior Reactor Engineer — date

Jim Trapp — 9/8/88
James M. Trapp, Reactor Engineer — date

Approved by: Jack Strosnider — 9/9/88
J. Strosnider, Chief, Materials and Processes Section — date

Inspection Summary: Inspection 50-219/88-24 on July 15, 1988 and July 18 through August 12, 1988

Areas Inspected: An unannounced inspection of the failure of Main Steam Isolation Valve NS03A Stem. The inspection included a review of the sequence of events, maintenance history, surveillance test history, stem material, industry experience and corrective actions.

Results: Within the scope of this inspection no violations were identified. One item remaining unresolved (88-24-1) is the identification of the root cause of the failure and the necessary action required to prevent recurrence. Therefore prior to returning to power operation from the 12R outage. The licensee is requested to submit to the NRC their proposed maintenance and surveillance program to ensure MSIV valve stem reliability.

DETAILS

1. Persons Contacted

GPU Nuclear Corporation

E. Fitzpatrick, Vice President and Site Director
*R. Barrett, Plant Operations Director
*K. Wolf, Radiological Eng. Mgr.
*J. Rodgers, Licensing
*D. Ranft, Mgr. Plant Engineering
*J. Barton, Deputy Dir. Oyster Creek
*R. Fenti, Mgr. QA Mods/Ops
*D. MacFarlane, Site Audit Mgr.
A. Rone, Plant Engineering Director
M. Radvaasky, Manager, Tech. Evaluations
D. Covill, Metallurgical Engineer
J. Charterina, Senior Engineer
R. Keating, Maintenance Supervisor

U.S. Nuclear Regulatory Commission

*E. Collins, Resident Inspector
*M. Markely, Resident Inspector
*P. K. Eapen, Section Chief Special Test Program Section
*A. Dromerick, Licensing Project Manager
*G. Sjoblom, Director, Division of Radiological Safety and Safeguards

The inspectors also contacted other licensee employees in the course of the inspection.

*Denotes those present at the exit interview on July 22, 1988.

2. Main Steam Isolation System Description

a. Design Basis

Two Main Steam Line Isolation Valves (MSIVs) are installed in each of two 24-inch Main Steam Lines. MSIVs NSO3A and NSO4A are the inboard and outboard valves, respectively, in the "A" steam line. MSIV NSO3B and NSO4B are the inboard and outboard valves in the "B" steam line. The MSIVs are containment isolation valves designed to isolate containment and control the release of radiation in the event of postulated accident conditions.

The Main Steam Isolation Valves are designed to close within three to ten seconds. The three second closure time is chosen to minimize the pressure buildup in the reactor vessel due to the quick cutoff of steam flow from the vessel. The ten second, maximum closing time, is based upon a steam line break accident and controlling the resulting loss of coolant and offsite dose rate. The normal opening time for the valve is in the range of 25 to 35 seconds to avoid pressure transients during valve testing.

b. Valve Design

The Main Steam Isolation Valves, manufactured by Atwood and Morrill Company, are 24-inch angled globe valves having a "Y" pattern body (See Figure 1). The MSIV contains an internal pilot valve. The end of the valve stem seats in the pilot valve seat which is located in the center of the main poppet. The pilot equalizes the pressure across the main poppet prior to lifting the main poppet off its seat. The first one inch of stem travel opens the pilot valve and engages the main poppet. The next 11" of stem travel lifts the main poppet. The full stem travel from full closed to full open is twelve inches.

In the backseated position the valve stem remains under tension. When backseated the main poppet is laterally positioned at the top and bottom. At the top the poppet contacts a stellite faced valve liner which protects the valve body from damage. At the bottom, three stellite faced guide ribs (part of the valve body) contact pads on the main poppet. When looking down into the valve body, one of the three guide ribs is positioned in the inlet flow in the lower portion of the valve body. The main poppet rests on this guide rib and it appears to be more susceptible to damage.

Each valve is controlled independently using a pneumatic control system. The controls are capable of opening, slow speed exercising and fast closing the MSIVs one at a time. Air for the outboard valves and nitrogen for the inboard valves are used to open the valves, while springs and/or air (nitrogen) pressure closes the valves. The springs are sized to close the valve in the event of a loss of air (nitrogen). The valves are administratively controlled to prevent opening when the pressure differential across the valve is greater than 160 PSI.

Redundant 95% open (5% closure) and fully closed limit switches operate indication lights in the control room to inform the operator of valve position. These limit switches operate based on valve stem position and are used to time the valve closure during the 5% and full valve closure tests. Two additional limit switches open when the valve has closed 10% to initiate a reactor scram signal. If one valve in each steam line closes, the reactor will scram, provided reactor pressure is greater than 600 psig while in startup or Run Modes.

c. Operation

The MSIVs are maintained in the fully open position during operation. The valves are 5% closure tested on a daily basis and full closure tested quarterly-in accordance with Technical Specifications. The closure time of the valve determines its acceptability.

3. Chronology of Events

A planned weekend load reduction was initiated to reduce reactor power level to less than 40% for flux shaping and to perform the Main Steam Isolation Valve (MSIV) closure test. At 0137 on July 9, 1988, the "MSIV Closure and IST test" was being performed. At that time, the "A" steam line inboard MSIV, NS03A, failed to fully close. Both the 5% (open light extinguishes) and the 10% closure (½ scram signal) indications were received. The steam line flow indication verified that MSIV NS03A was not closed. NS03A was reopened and a second attempt to close the valve was made with similar results. The valve was declared inoperable.

At 0143 the "A" steam line, outboard, MSIV NS04A was successfully closure tested. NS04A was closed to isolate the "A" steam line.

At 0442 MSIV NS04A was opened to reduce the pressure differential across MSIV NS03A. An attempt was made to close MSIV NS03A using the slow closure test push button. The 5% closure was the only indication received. A third attempt was made to close MSIV NS03A using the normal operating switch with similar results to the two previous tests. MSIV NS04A was closed and its operator disabled in accordance with the Technical Specification 3.5(3.), four hour action statement.

At 0637 a further attempt was made to close MSIV NS03A with MSIV NS04A in the closed position. MSIV NS03A "CLOSED" valve indication was received in 40 seconds (Normal Closure time greater than 3 seconds, less than 10 seconds). The valve was then reopened in 23 seconds. MSIV NS03A was cycled two additional times with closure times of 4 seconds and opening times of 23 seconds. The 5% closure test was performed on MSIV NS03A twice. The 5% closure times of 97 seconds and 99 seconds were comparable to recent closure time test results.

A test program was developed to verify the reliability of NS03A. This program was described to the NRC prior to implementation. At 1306 two additional full closure tests were performed on MSIV NS03A with acceptable results. MSIV NS03A position switch was placed to open and the valve was declared operable.

At 1542 the Technical Specification action taken on MSIV NS04A was cleared and the valve was opened. After opening MSIV NS04A, "A" steam line flow indication was unchanged. This was the first indication that actual valve position was different than the indicated valve position. Review of computer generated graphs indicated that when NS04A was opened 'B' steam line flow decreased by about 100,000 lbm/hr. This revealed that NS03A was almost fully shut and that NS04A was functioning.

The steam flow indication was verified using the Main Steam line break sensors. A visual ir :ction of MSIV NS04A by the licensee indicated normal operation. A. :/33 MSIV NS04A was closed and its operator disabled in accordance with Technical Specifications. At 1848 a plant shutdown was commenced. On July 13, 1988, the valve was disassembled and was found to have a broken 17-4 PH (precipitation hardening) stainless steel stem. The guide rib in the inlet flow was found to have wear in excess of manufacturer's specification and two of the four gland nuts were discovered to have vibrated loose.

4. Maintenance History

A summary of the maintenance history of the Main Steam Isolation Valves is provided in Table 1. MSIV NS03A which experienced stem separation and severe guide rib wear has had a history of maintenance problems. This valve exhibited guide rib damage in 1978, 1980, 1982 and during the present disassembly. The guide ribs were repaired by stellite (a cobalt based wear resistance alloy) weld buildup and machined. Until the present MSIV repair of NS03A and NS04A, only NS03A had experienced rib damage.

During the present disassembly of NS04A, after failing a Local Leak Rate Test (LLRT), rib damage in excess of Manufacturer's Specification was detected. Although the stem was found to be free of cracks (See Section 7), the poppet was found to be improperly aligned with the guide ribs. The misalignment caused incomplete contact between the pads on the poppet and guide ribs. This caused the partial guide rib wear pattern seen on the guide ribs. NS04A will be repaired by replacing the valve stem and repairing the guide ribs. The valve will be reassemblied with proper poppet alignment. The valve will be LLRT prior to startup.

The valves on the "B" steam line have required less maintenance than the valves on the "A" steam line. The "A" steam line valves have been disassembled nine times compared to four disassemblies of "B" steam line valves. Furthermore, MSIV NS03B has operated since 1974 without failing an LLRT and without disassembly.

5. Surveillance History

The inspector reviewed the data for the daily 5% closure test. The closure time for valve NS03A exceeded the 90 second closure time acceptance criteria from January 1988 until stem separation in July 1988. MSIVs closure times for all other MSIVs were within the 30-90 second acceptance criteria.

On April 21, 1988, while attempting to perform the 5% closure test on MSIV NS03A the valve did not close. Reactor power was reduced, and the full closure test was performed. Following the full closure test the 5% test was successfully repeated.

The inspector reviewed the full closure test data. The test data were found to be acceptable.

In May of 1987, the "open" limit indication for valve NS03A failed. the repair required entry into the drywell and was not completed until September 1987. For a period of approximately five months the 5% closure test was performed using the 10% closure, with half-scram signal to indicate valve movement.

The Local Leak Rate Test (LLRT) failures for the MSIVs are provided in Table 1. The failure rate of the "A steam line exceeds that experienced in the "B' steam line.

6. Industry Experience

The inspector reviewed industry experience and found that five MSIV stem failures in similar Atwood and Morrill valves occurred at two other nuclear plants. The following is a discussion of these failures.

Hatch 1 1985

In July 1985 Hatch 1 experienced an MSIV stem failure of the "A" inboard MSIV. The apparent cause of the failure was attributed to improper backseating of the valve causing excessive poppet vibration. The improper backseating is believed to have occurred between January 1985 to July 1985. Following this failure Hatch 1 ensured positive indication that the valves were properly backseated.

Hatch replaced the stem and re-assembled the valve using new Atwood and Morrill parts. Five months later while technicians were taking the same valve apart for maintenance the stem was found to be broken in the same location. The failure mode was apparently the same as in the first event. Further inspection of the valve showed wear in the poppet pad to rib guide clearances. In addition, inspection of the other MSIVs showed that the "B" inboard valve had a similar crack.

Hatch 1 sent two of the failed 17-4 PH stainless steel stems to Battelle Laboratory for metallurgical examination along with six stems from other valves which did not fail. Battelle concluded that the cracks in the "A" and "B" inboard 17-4 PH 1100°F aged valve stems most likely initiated by fatigue in the relief groove region immediately above the backseat seal surface on the stem. Those cracks then propagated by fatigue. The "A" stem crack propagated by fatigue approximately 3/4 of the way across the stem cross section until the remaining section was unable to support the service stresses and failed by overload in a ductile-rupture mode. The "B" stem crack propagated through the stem cross section about the same amount, but it was removed from service before complete failure. No cracking was observed in any of the six unbroken stems, four of which were found to be manufactured from type 410 martensitic stainless steel. It is noted that 17-4-PH 1100°F aged stems were found to be of much higher strength (155000 psi - 161000 psi) than the 410 stainless stems (116500 psi-125000 psi); the higher strength is generally accompanied by higher fatigue strength. Structural Integrity Associates performed a stress and fatigue analysis of the failed stem for Georgia Power Company. Based on the SIA and Battelle analyses, it was concluded that cracking of the valve stems appeared to be attributable to high cycle fatigue initiation and growth caused by the out-of-design clearance condition between the valve poppet and guide ribs which allowed the poppet and stem to vibrate excessively in the normally open valve position. Excessive guide rib wear was observed on the two valves in which cracking was observed. The wear increased the clearance between the poppet and one of the guide ribs from the design basis value of .020 inch to as much as .083 inch. This condition permitted the poppet to vibrate over a larger range, thereby increasing the stresses on the stem. The situation was aggravated by the presence of a severe stress concentration factor from a machined groove.

In April 1978 Pilgrim experienced an MSIV stem failure. Inspection showed the 17-4 PH stem had sheared at a point where the pilot stem is tapered. A GE report indicated that the failure was due to high cyclic bending fatigue with the final ductile failure approximately 5% of the total area. The stem was replaced (in kind, 17-4 PH) and the valve returned to operation. In September 1982 the same valve failed and inspection showed an identical failure. A laboratory tested the stem and their conclusion was that the most probable cause of failure was fatigue as the result of one or more overload conditions in bending at the machined notch on the stem.

Additional inspection showed wear resulting in increased poppet pad to rib guide clearances.

7. Failure Analysis of MSIV NSO3A Broken Valve Stem at Oyster Creek

On July 15, 1988, the inspector visually examined the failed 58" long stem after its removal from valve NSO3A. The failure occurred in the stress relief groove in the transition area between the 2.245" diameter and 2.725" diameter sections. The specific root profile is to be established by GE in their failure analysis. The fracture faces exhibited smooth, rose colored oxidized surfaces in approximately 75% of the area and a rough, appearing type of fracture in the remaining 25% , the latter apparently representing the ductile failure of last portion of the stem. No evidence of gross plastic deformation ("necking down") at the fracture ends was observed. The lack of plastic deformation coupled with the resultant fracture pattern is generally indicative of high cycle fatigue as being the mechanism of failure. It is noted that no visual evidence of corrosion (pitting or wastage) or surface abuse (e.g. gouges) was observed by the inspector in the the vicinity of the failure. Evidence of surface abrasion was observed for about 2" along the length of the stem at the pilot end of the stem which may have occurred during operation, or during installation or removal. The licensee also reported excessive wear between the valve poppet pad and the rib guide. The extent of the wear was approximately 4 inches along the rib starting at the top of the rib.

The broken stem was shipped to GE San Jose, California for metallurgical examination. The preliminary results to date indicate that (1) the stem was manufactured from 17-4 PH stainless steel; (2) the failure mechanism was high cycle fatigue which originated at a single location and had a torsinal component; (3) the surface hardness was Rockwell C35-36 indicative of 1100°F aged material; and, (4) the microstructure was typical of properly solution annealed 1100°F aged material. The final GE report is expected to be reviewed by the inspector at a later date.

The inspector also witnessed liquid penetrant inspection of an unbroken stem after it had been removed from MSIV NS04A. The inspection was performed in accordance with GPU Procedure 6130-QAP-7209.05. The inspection was limited to the transition area between the 2.245 and 2.725 sections because of radiation exposure. The liquid penetrant inspection failed to disclose any indications at or away from the stress relief groove which was measured to have a 5/32" radius and 0.121" depth. The radius was specified as 1/16" on Atwood and Morrill Company Dwg. 23030-C dated February 15, 1973. The depth of the groove was not specified. No evidence of corrosion pitting or wastage was observed. The NS04A stem is scheduled to be replaced because it was bent during its removal.

8. Stem Material History

The inspector reviewed certified material test reports CMTR's of the broken stem in MSIV NS03A and the unbroken stems in NS04A and NS04B. The test reports indicated the material to be 17-4 PH (precipitation hardening) - 1100°F aged material. Although no CMTR was available for the stem in valve NS03B the material was believed to be type 410 or 416 stainless steel as originally specified by Atwood and Morrill. It is noted that type 410 or 416 stainless stems were replaced with 17-4 PH stems sometime in 1978. As indicated in Table 1 the stem MSIV NS03B had never been replaced since its installation in 1974. The replacement stem for MSIV NS03A is 17-4 PH 1100°F aged material.

In addition to changes in stem material indicated above, the Atwood and Morrill MSIVs have undergone various changes in design since their initial fabrication. With regard to Pilgrim, Hatch and Oyster Creek the major changes have included (1) increase in stem diameter from 1.75" dia. to 2.245; (2) addition of a poppet anti-rotation device; (3) addition of a self aligning pilot poppet seat; and, (4) addition of a stress relief groove in the transition between the 2.245 and 2.725" diameter sections. The self aligning pilot poppet has not been installed in the OC valves.

9. Corrective Actions

The short term corrective action to repair MSIV NS03A is to replace the stem and return the guide ribs to the manufacturer's specifications. The valve will be local leak rate tested prior to restart. NS-04A will be repaired by replacing the valve stem and repairing the guide ribs. The valve will be reassembled with proper poppet alignment. The valve will be LLRT prior to startup.

The following short term corrective actions will be taken:

1. Instrumentation will be installed on all four MSIVs prior to start up to attempt to gain insight into the source of vibration.

2. A technical specification change has been submitted to eliminate the requirement to perform the daily closure test.

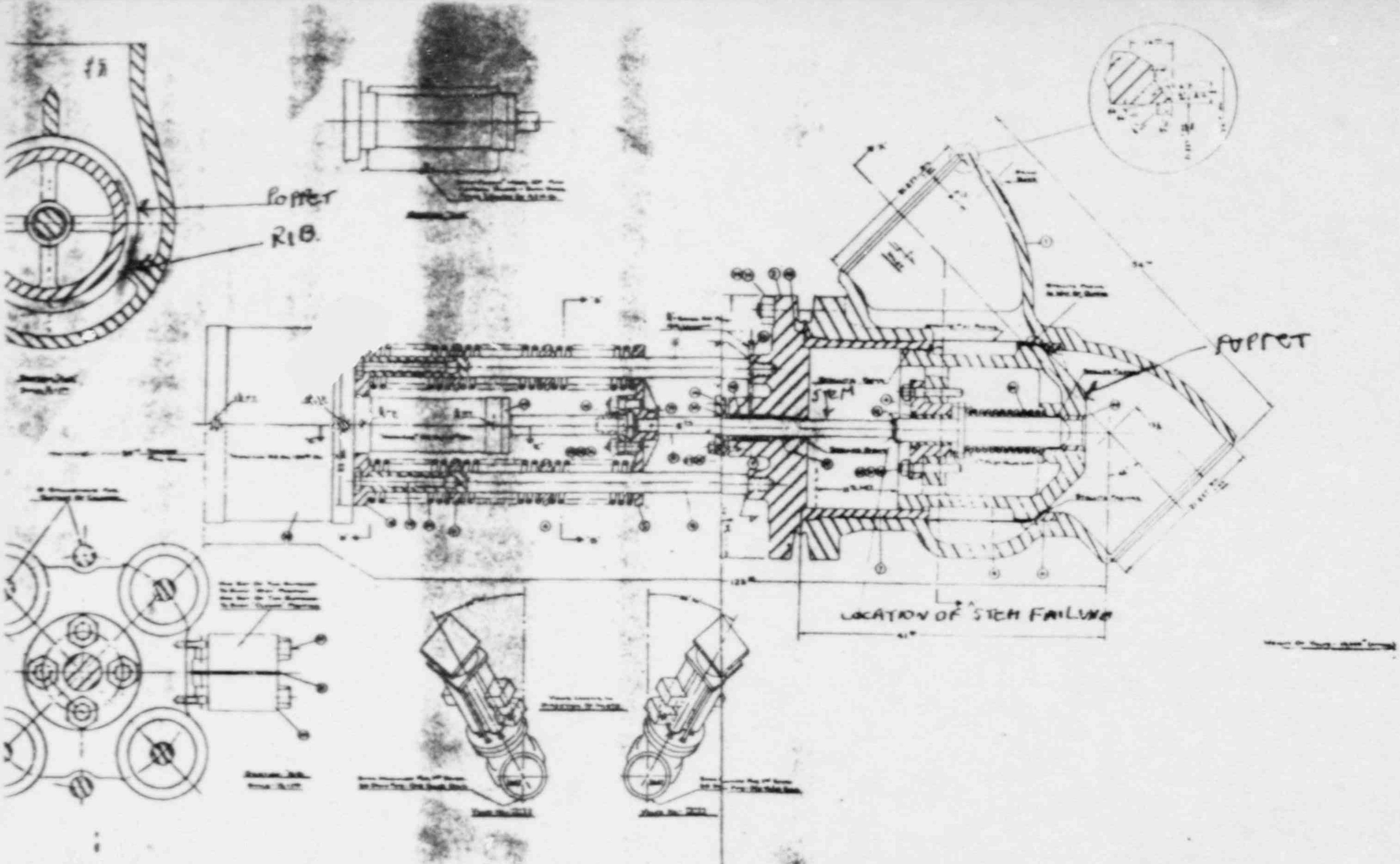
The scope of the long term corrective actions to eliminate the vibration on the "A" steam line MSIVs is not defined. The vibration instrumentation installed should be the key in determining the root cause of the vibration. The root cause determination of stem failure will be maintained as unresolved item (88-24-01). The closeout of this unresolved item is projected to be the conclusion of the 12R Refueling.

10. Conclusions

The licensee has performed a preliminary "Safety/Environmental Determination and 50.59 Review" (000411-009) addressing the valve stem failure. The Safety Determination concluded the following:

> The failure mechanism of the NS03A valve was determined to be high cycle fatigue resulting from excessive steam induced vibrations of the poppet/stem assembly. The failure which occurred in a machine groove of high stress concentration may have been related to a combination of system and operating conditions unique to NS03A that eventually caused excessive clearance between the poppet and guide ribs. These were (a) a series of 10% closures which occurred in summer of 87 and (b) high piping vibration in "A" steam line compared to "B" steam line. The NRC inspectors found this preliminary determination to be a reasonable explanation of the failure.

No written material was provided to the licensee during this inspection. The licensee representatives did not indicate that this inspection involved any proprietary information.



GPU NUCLEAR CORPORATION OYSTER CREEK NUCLEAR GENERATING STATION UPDATED FINAL SAFETY ANALYSIS REPORT	24" - GLOBE BODY MAIN STEAM ISOLATION VALVE - WITH CYLINDER OPERATOR	
	REV. 0, 12/84	FIGURE 5.4-4 A

TABLE 1

MSIV MAINTENANCE HISTORY

YEAR / MSIV	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
NS03A							RS LS RR FL			RS LS RR FL		RS LS RR FL		RS LS		FL				RS ? RR ?
NS04A						RS LS				RS LS					FL	RS LS FL			RS LS FL	? ? ? FL
NS03B						RS LS														
NS04B								RS LS FL	RS LS						FL	RS LS				

RS - Replaced Stem

LS - Lapped Seats (Main and/or Pilot)

RR - Repaired Guide Ribs

FL - Failed LLRT

? - No Data