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SUBJECT: Discusses pump damage discovered in emergency svc water & RHR sys on 860522 when low flow & low motor amps experienced. Caused by cavitation resulting from running pumps at low rate. Suction bells & impellers replaced.

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JUN 30 1986

Director of Nuclear Reactor Regulation
Attention: Ms. E. Adensam, Project Director
BWR Project Directorate No. 3
Division of BWR Licensing
U.S. Nuclear Regulatory Commission

SUSQUEHANNA STEAM ELECTRIC STATION
ESW AND RHRSW PUMP DAMAGE
PLA-2665 FILE R41-2

Dear Ms. Adensam:

The purpose of this letter is to provide information on the pump damage recently discovered in the Emergency Service Water (ESW) and Residual Heat Removal Service Water (RHRSW) systems at Susquehanna SES. Failure of the C ESW pump was discovered when low flow and low motor amps were experienced on May 22, 1986. Inspection revealed that the suction bell wall had been penetrated around its entire circumference by what appeared to be cavitation. An inspection of the A ESW pump on May 24, 1986 revealed suction bell wall penetration in the same location. A decision to shut down both units was made immediately following the discovery of the damage to the A ESW pump. Inspection of the RHRSW pumps also revealed damage due to cavitation.

In response to these pump problems, all ESW and three of four RHRSW pumps have been visually inspected, short term corrective actions taken, inspection schedules are being developed, and long term preventative measures are being evaluated.

The ESW and RHRSW pump problems are individually discussed below.

EMERGENCY SERVICE WATER

1. Cause of Failure

   Inspection of the ESW pumps revealed the following:

   o The A pump showed signs of cavitation damage on the high pressure side of its impeller vanes. The cavitation had eroded through the wall of the impeller vanes in some areas but had not grossly changed the overall shape of the vanes. Cavitation had eroded through the suction bell wall in the area of the impeller around most of the suction bell circumference. This pump had run approximately 17800 hours.

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- Inspection of the B pump revealed that cavitation had considerably eroded the suction bell wall, but the only penetration was one small pinhole. The impeller showed signs of erosion on the high pressure side of its vanes at the suction end. However, the vanes had not been penetrated and had retained their original shape. This pump had run approximately 17800 hours.

- On the C pump, cavitation similar to that seen on the A pump suction bell had penetrated the suction bell wall around its entire circumference. The cavitation also eroded away the web of the suction bell, allowing the suction bell to fall into the pump pit. The impeller vanes had been eroded away by cavitation on their suction end. The shaft had broken in the area of the impeller. The C pump had run approximately 19000 hours before the failure.

- Similar to the B pump, the D pump showed cavitation damage of the suction bell that did not penetrate the suction bell wall. The impeller vanes showed only minor cavitation damage on their high pressure sides. This pump has run approximately 11700 hours.

Inspection of the suction bells from all ESW pumps and their impellers revealed that cavitation originates on the high pressure side of each impeller vane at its suction end. This is indicative of impeller suction recirculation cavitation. This type of cavitation occurs when the pump is run at flows which are significantly below the design flow. The cavitation erodes the suction bell wall. The impeller also erodes but at a slower rate. Once the suction bell wall is penetrated, erosion of both the suction bell wall and the impeller is accelerated as water is drawn through the suction bell penetrations.

Cavitation due to low NPSH did not contribute to the failure since impeller cavitation damage was not found on the low pressure side of the impeller vanes. In addition, a comparison of available NPSH and required NPSH indicates that adequate NPSH will be available at all normal operating conditions and during an accident condition in which the spray pond is at its lowest possible level and its highest temperature.

The pump pit design was evaluated. Based on an inspection of an evacuated pump pit and a review of the pit drawings, the pump pit design was determined to be acceptable and consistent with Byron-Jackson design philosophy with regard to pump-to-back wall clearances and pump-to-floor clearances. While the pump pits are nearly twice as wide as required, this condition is not considered to have a detrimental impact, since the average pit velocity is very low (approximately .25 ft/sec). Also, visual inspection of B and D pump operation revealed no pump pit surface vortexing or turbulence, indicating that major vortexing or turbulence at lower pit depths is unlikely.

Although corrosion was detected on the submerged pump components, corrosion is believed to be only a secondary contributor to the pump

failures. Also, there were no signs of erosion due to intake silt or sand.

From the above inspections, PP&L concluded that impeller suction recirculation cavitation was the major contributing factor to the ESW pump failure. Again, this type of cavitation occurs when a pump is run at flows significantly lower than its design flow (approximately 6000 gpm). Operation at lower flow creates mismatches of the flow angles within the pump and causes water to recirculate back towards the suction. The recirculating currents cause local pressure zones which are below the vapor pressure of the water. This causes vapor bubbles to form which collapse when a higher pressure zone is reached, eroding the local material.

2. Short Term Corrective Actions

Repair of all four ESW pumps was accomplished by the replacement of all suction bells and impellers. The replacement impeller is NiAl Bronze. This material has a higher resistance to cavitation damage than that of the original impellers. The replacement suction bells are made of the original carbon steel material.

Flow balances have been performed for both ESW loops to verify that design flow is still being provided to all cooling loads during two pump ESW operation.

3. Expected Lifetime

PP&L estimates that, based on Susquehanna operating experience, the suction bells have an expected life of 15,000 hours. The replacement impellers are expected to have a lifetime of 40,000 hours if operated above 3000 gpm. As indicated by the B and D pump damage, cavitation damage at the impeller is not expected to be significant if the suction bell has not been penetrated. Therefore, pump performance will not be significantly reduced until penetration of the suction bell occurs. Rapid degradation of the suction bell and impeller is expected once the suction bell has been penetrated.

4. Continued ESW System Operation

A review of current system operating configurations shows that few options exist for operating the system (given the current design) in a way which avoids cavitation. Normally, all four diesel generators are aligned to the A loop of ESW. This is the only configuration that meets single failure criteria since the diesels can only auto-transfer from A loop to B loop. Each ESW loop is flow balanced with all diesels aligned and two operating pumps. However, all components on a given ESW loop will receive adequate flow with only one pump in operation if the diesels are not aligned to that loop. Neither loop will provide design flow to its components with the diesels aligned when only one pump is in operation.

When the loop supplying the diesels is run with two operating pumps, each pump delivers approximately 3500-3900 GPM. Pump operation in this range is likely to cause suction recirculation cavitation.

The loop of ESW that does not serve the diesels (usually the B loop) is normally run with only one pump at approximately 1000-1500 gpm. This operation causes suction recirculation cavitation. Future design changes will be considered in order to avoid this operation. Two pump operation in the ESW loop that does not serve the diesels will also be avoided.

In addition to the operational and system design changes which are currently under investigation, modifications to the pumps will also be considered. Continued operation of the ESW pumps in the cavitation range is acceptable on the basis that (1) the root cause of the pump damage is understood, and (2) expected lifetimes of pump components are determinable based on inspection findings and operating history.

RESIDUAL HEAT REMOVAL SERVICE WATER

1. Cause of Damage

Three of the four RHRSW pumps have been inspected. The extent of the damage and run times of each is listed below.

PUMP	DAMAGE	RUN TIME (HRS)
1A	Cavitation damage to the impeller liner. The damage is 360° around the liner approximately 1" wide and 1/4" deep in most areas; several areas were 3/8" deep and the deepest cavity is 0.469". The impeller was not damaged.	8882
1B	Cavitation damage to the impeller liner. The damage is 360° around the liner approximately 3/4" wide and 1/4" deep on the average, 11/16" deep max. The lower part of the impeller felt smooth.	7306
2A	Slight roughness in impeller liner due to cavitation. The affected area is about 1/16" deep and 360° around the pump.	4154
2B	Not inspected.	6511

The damage to the RHRSW pumps has not been detrimental to performance of their design function. 1A and 2A pumps have been able to pump 9000 gpm to

their respective heat exchangers (design flow) during the running of test procedure TP 054-065.

From the inspection of the RHRSW pumps, PP&L has concluded that the impeller liner degrades before any significant damage is seen on the impeller. The liner damage does not seem to cause a noticeable drop off in pump performance as evidenced by the flow data.

The cause of the pump damage is due to cavitation which results from running the pumps at a low flow rate. Low flow rates cause flow separation and turbulence at the leading vane tips, known as suction recirculation. The turbulence, and high velocities, locally reduces the static pressure of the water causing it to flash. The vapor bubble moves to a higher pressure area in the impeller and implodes on itself setting up a hydraulic shock wave that impacts the impeller, adjacent parts, and the impeller liner.

The effects of vortexing and insufficient NPSH as a cause of the damage has been reviewed by PP&L and has been concluded not to be a contributor.

2. Short Term Corrective Actions

RHRSW pump impeller liners have been replaced in the 1A and 1B pumps. Cavitation damage to the 2A pump was minimal and impeller liner replacement was not warranted at this time. Inspection of the 2B pump, and possible impeller liner replacement, is expected to occur during the Susquehanna SES Unit 2 first refueling outage.

3. Expected Lifetime

The subject damage to the RHRSW pumps can be avoided by operating the pumps above 50% of design flow; specifically 75-100% of design flow is desirable. The RHRSW system design and method of operation will be reviewed to determine what changes are possible to avoid recirculation cavitation.

Expected lifetimes of RHRSW pump components will be determined based on inspection findings and operating history.

4. Continued RHRSW System Operation

Continued operation of the RHRSW pumps is acceptable on the basis that (1) the root cause of the pump damage is understood, and (2) expected pump lifetimes are determinable based on inspection findings and operating history. To enhance system reliability, PP&L is considering upgrading the RHRSW pump impeller liner material to one that is more resistant to cavitation damage.

Long term solutions to the ESW and RHRSW pump cavitation problems are still being evaluated. Periodic inspections will be conducted to ensure pump

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integrity. We believe our short-term planned actions are more than adequate to maintain the safe operation of the ESW and RHRSW systems.

Requests for additional information may be directed to Mr. L. M. Olson (215) 770-7859.

Very truly yours,

H. W. Keiser
Vice President-Nuclear Operations

cc: M. J. Campagnone USNRC
L. R. Plisco USNRC

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