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August 9, 2004

Memorandum

To: Todd Hottovy, Equipment Reliability Manager

CNS System Engineering Letter Log Number 04-7002

From: Richard Fili, System Engineering Manager

Date: 8/9/2004

Re: Assessment of the Survivability of the Service Water Pumps if Gland Water were Lost

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Problem: Given conditions that existed at Cooper Nuclear Station during the period January 21, 2004, to February 11, 2004, if gland water to a service water pump is inadvertently discontinued, can the pump operate for a minimum of 90 minutes? Further, if gland water is restored after 90 minutes, can the service water pump reasonably function for an additional 48 hours?

Conclusion: A temporary loss of gland water for 90 minutes will not severely damage or incapacitate the pump. Upon restoration of gland water after 90 minutes, the pump will at least operate for 48 hours more.

Some damage to the guide bearing bushings may occur, especially those bushings near the center of the pump shaft above the water line, and some damage to the upper packing may occur. The damage in both cases will primarily result in moderately larger clearances in the affected components that become dry, and a corresponding moderate increase in lateral pump vibrations. Packing leakage will also increase when gland water is restored.

Damage will not be so severe, however, that vibrations will be excessive and destructive. The pump will be able to operate and function in a reasonable manner for at least another 48 hours afterwards when gland water is restored.

Discussion: The given conditions were as follows.

Time frame: January 21 to February 11, 2004.
River elevation: 875.5 to 877.5 feet MSL.
Service water temperature: <45 degrees F.
Pump running at 5500 gpm.
Average discharge pressure, 50 psig.
Gland water flow, 6 to 8 gpm to the enclosing tube at 16 to 24 psi.
The following material conditions existed as of March 2003: 1). New pump assembly, packing, coupling, shafts, cutlass bearings, and impeller. 2). Rebuilt outer column, discharge nozzle, registers, and spider bushing supports.
IST vibrations are normal; concentricity and mass eccentricity are all normal.

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The four service water pumps at Cooper Nuclear Station are Byron-Jackson 28KXL type, mixed flow, single stage, vertical pumps. They operate at 1180 rpm, have a rating of 8000 gpm, and are driven by a 300 hp electric motor. The pump impeller has balance holes.

The following components were considered and it was determined that they would not be impacted by the loss of gland water:

- Loss of gland water does not directly affect the motor-driver. Its bearing system is lubricated by oil and is independent of gland water.
- Loss of gland water does not directly affect the lower bronze bearing located below the impeller. It is immersed in the "E" bay and will self lubricate sufficiently even if gland water is lost.
- Loss of gland water does not directly affect the impeller and wear ring. They are also immersed in the "E" bay and will self lubricate even if gland water is lost.

Loss of gland water primarily affects the rubber, Cutless brand bushings that are spaced typically five feet apart along the length of the shaft from the bottom to the top. There are ten Cutless rubber bushings. There is also one bronze bearing located below the impeller. Loss of gland water also affects the packing. The packing box will not receive water and will dry out.

If gland water is removed while the pump is running, the following will occur. The water level in the enveloping tube will drop slightly below that of the "E" bay. Assuming that the river is at an elevation of 875.5', then three of the Cutless bushings will still have water for lubrication. Intermittent dry contact between the upper seven bushings and the pump shaft, and the packing and the pump shaft will then occur.

<u>Bushings:</u>
Loss of gland water in this scenario would deprive the upper seven Cutless bushings of lubrication water. The lower three bushings, like the lower bearing, will remain immersed in the "E" bay and will not be deprived of lubrication water.

At CNS, when the pumps are refurbished and re-installed, it is the practice to turn the pump by hand when checking the lift adjustment. This is a procedural quality control step in the assembly of the pump that is required to be witnessed and verified. This is important because it ensures that the pump has no significant points of binding or friction. Further, when the lift is reset, the rubber bushings are already wet. Gland water will have already been supplied to the pump when this check is made. Since the rubber is slightly hydrophilic, they will have already swelled to the size they will be in service.

Non-lubricated contact between the bushings and the smooth, polished pump shaft will eventually cause some bushing surfaces to heat up and form a hard glaze at the surface. Heating nitrile rubber causes it to first soften, and then as heating progresses further, it becomes brittle, hard and charred. As nitrile rubber heats up, it also volatilizes and outgases. The net result is that the heat-damaged rubber loses volume and shrinks.

<u>Packing:</u>
The packing box, located at the top of the pump, will not receive water for lubrication and cooling. Like the bushings, it will heat up on those surfaces where the packing directly contacts the shaft. This localized heating will damage the packing. It will cause heat-hardening, scorching, outgassing, and shrinkage due to outgassing, and the clearance will open up. This will allow higher leakage through the packing following restoration of gland water flow. The higher leakage will not adversely affect the function of the pump or motor.

Motor Overcurrent Trip Due to Seizure or Drag:
It may be hypothesized that the Cutless bushings will "grab" the shaft and cause it to seize. This is improbable unless there is significant misalignment that has occurred since the pump was re-installed. The pump shaft cannot contact all the rubber in the bushing, that is, the shaft cannot be grabbed on all sides by the rubber. At most, with a continuously applied lateral force, the shaft can only contact no more than half of a bushing's inside diameter, that is, about 180 degrees of the inside diameter, at one instant. If such a misalignment has occurred since re-installation, IST vibration measurements, electrical current measurements of the pump motor, or flow and discharge pressure measurements would detect the problem. Further, because the pump is vertical and the impeller is at the bottom of the shaft, the shaft is self-centering. The weight of the pump combined with the axial loads due to pumping water straight up through the column keeps the pump shaft directed downward and centered.

It is true that drag on the shaft will be increased if the upper bushings run dry. However, the pump motor-driver is rated for 300 hp continuous operation with 15% excess capacity. It has more than enough torque to overcome the increase in drag by intermittent contact with dry bushings. A check for potential harmonic vibration effects that might occur found nothing significant, although lateral vibrations will increase as bushing clearances open up.

As noted previously, the motor has a generous amount of torque available. The dry dynamic frictional coefficient of pump packing material is significantly less than that of dry nitrile rubber. As the packing that is in direct contact with the shaft heats up, its material properties will degrade and the packing material will also readily be torn and sheared away by friction until the inside diameter "wallows out" to match the lateral movement of the shaft. This obviates the likelihood of seizing by the packing.

Shaft Failure:
It may be hypothesized that the shaft could fail due to increased frictional drag or vibration. As previously discussed, it is improbable that the bushing or the packing will develop enough drag to seize the shaft. It is concluded that a properly maintained pump will be able to withstand the additional drag caused by the dry bushings and packing with no impact to the shaft mechanical strength. Also, as discussed below, the Johnston Pump Company performed a study of the possible vibration problems that might result from the posited loss of gland water condition. A computer model study using XLRotor software was conducted and it was concluded that there were no significant vibration problems.

Operational Experience (OE):
Anecdotal information from various plants has been obtained by both CNS and Mr. Cugal from the Johnston Pump Company that indicates service water pumps of the type used by CNS have successfully operated for short periods of time without gland water. One of the difficulties with citing operational experience information (OE) is that when no direct failure occurs or when there is no regulatory reporting requirement, the event is not in an OE database. Non-anecdotal documentation of this type of success or non-failure is scarce.

Searches in the INPO Nuclear Network database, INPO Plant Events database, along with searches by the Johnston Pump Company and an independent consultant, have not yielded any OE experience that is in disagreement with our findings. Conversely, there is evidence that shows that pumps of our design, and in good operating condition, have not failed for short periods of time without gland water.

Corroborative Data:
Johnston Pump Company, an Appendix B certified pump company, was contacted and asked to assess the same condition: loss of gland water to a CNS service water pump. In a report, JP04-20 Rev.2, authored by Michael Cugal, P.E., and checked by Lanka Pannila, P.E., they conclude the following.

> We believe that given the ample motor horsepower and the good existing maintenance practice in this case (alignment, good fits, and registers, etc.), the pump could have survived 90 minutes of "dry" operation. When the gland water supply was re-introduced, the pump could have operated (possibly with higher vibration and some damaged bearings [bushings]) for an additional 48 hours.

To further study the possible vibration problems that might result from the posited loss of gland water condition, a computer model study using XLRotor software was conducted by the Johnston Pump Company. The 54 page detailed report, JP04-18 Rev.0, concluded that there were no significant vibration problems.

A report, *ESW Pump Operating Evaluation*, by Michael C. Mancini Consulting Services compares the Cooper Service Water pumps with posited loss of gland water condition to similar designs in other plants. The report shows that a properly maintained pump will have minimal bearing wear compared to a poorly maintained pump under the same operating conditions. This report identifies that the CNS attention to tighter fit up tolerances, along with the conditions of assembly and operation, afford the same type of success as the best plants in the comparison with minimal wear to bearing surfaces..

Preparer: Randall Noon — Randall Noon — Date: Aug. 9, 2004

Reviewer: Dwight Vorpahl — Dwight Vorpahl — Date: 8/9/04

Approved by: Ricky Fili — Ricky Fili — Date: 8/9/04

ENCLOSURE 1 TO ATTACHMENT 3

ENGINEERING EVALUATION REGARDING SHORT TERM DRY-RUN OF RUBBER COLUMN BEARINGS

JP04-20 REV. 02

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NRC DOCKET 50-298, DPR-46