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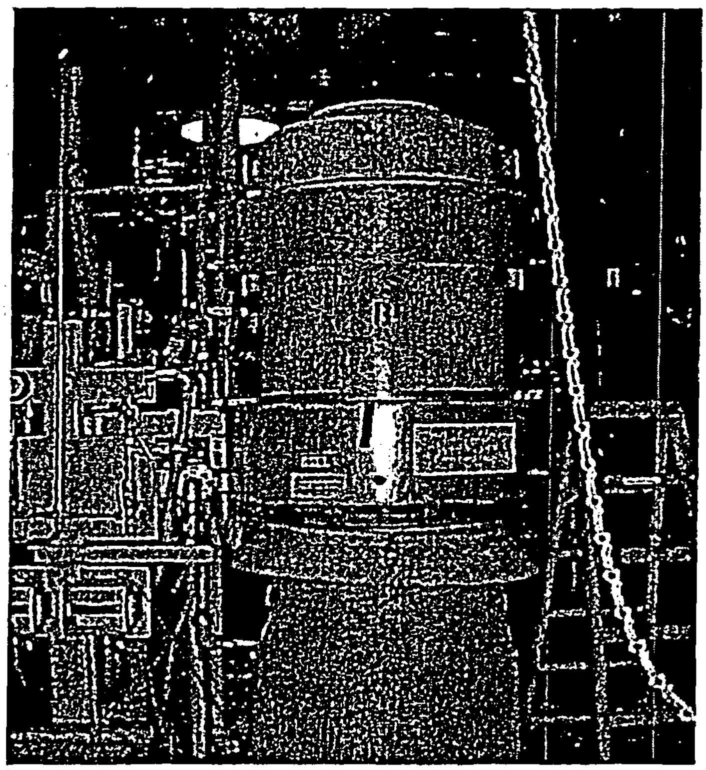
# Assessment of the Survivability of the Service Water Pumps when Gland Water was Lost



Randall Noon, P.E., preparer
Cooper Nuclear Station

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J-40

Premise

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 90 minutes or more? Further, if gland water is restored afterwards, can the service water pump reasonably function for 48 hours more?

The given conditions are 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.
IST vibrations normal.

Discussion

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.

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 bushing located below the impeller. It is immersed in the river and will self lubricate sufficiently even if gland water is lost.

Loss of water does not directly affect the impeller and wear ring. They are also immersed in the river 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 bushing located below the impeller.

Loss of gland water could deprive the upper six or seven Cutless bushings of lubrication water, depending upon the level of the river at the time of the event. The lower three or four bushings, like the lower bearings, however, will remain immersed in the river and will not be deprived of lubrication water.

The rubber bushings have an inside diameter of 2.193 to 2.199 inches, and are 7.5 inches long. There are ten flutes cut into the rubber to allow passage of water. The shaft that fits through the bushing is nominally 2.1875 inches in diameter.

The bushing material that contacts the pump shaft is nitrile rubber, which is also called buna-N (1). The maximum service temperature for nitrile rubber is 250 degrees F (2)(3). Nitrile rubber is often used for rotary shaft seals and o-rings. Depending upon the specific grade, the tensile strength at room temperature can be about 2000 psi (4).

The rubber bushings in the service water pump do not carry significant bearing loads; they are bushings not bearings. As such, they act as "bumpers" for any excess lateral motion of the pump shaft. As is noted in *Kent's Mechanical Engineers' Handbook*, 12th Edition, the "Design and Production" Volume, page 12-46:

> *Rubber is used to line bearings where only water is available as lubricant and where bearing pressure is light. It is useful in guide bearing bushings for vertical revolving shafts, and in stern tube bearings in ships.*

Because the pump shaft is relatively long, about 45 feet, any centerline or mass distribution eccentricities in the pump shaft can cause the shaft to vibrate or wobble as it rotates. If no Cutless bushings were present, lateral motion would be greatest near the center of the shaft and least at the two ends where the shaft is not free to move laterally.

By placing a single bushing at the center of the pump shaft, the maximum lateral motion at that point is reduced to the clearance dimension. This effectively divides the pump shaft then into two smaller shafts, with smaller lateral wobbles at their midpoints. With ten Cutless bushings in place, the pump shaft is effectively similar to nine short shafts that wobble slightly at their midpoints.

The pumps were originally supplied to CNS with bronze bushings. About ten years ago, rubber Cutless type bushings were substituted for the bronze bushings because they tolerate river sand better. Since rubber is softer and more resilient than bronze, occasional contact between the pump shaft and the rubber surface of the bushing does not cut or gall the 410 hardened stainless steel pump shaft. The rubber type bushing also provides better vibration damping.

Typically, when gland water is supplied to a service water pump, water flows downward through the bushings. It flows through the fluted slots in the bushing, and it flows through the clearance between the shaft and the bushing I.D.

A typical gland water flow rate is 5 to 10 gpm. Five gpm is equivalent to 0.668 cubic feet of water per minute. Since the annular space between the enveloping tube and the pump shaft is about 7.75 square inches, the flow velocity in this space is about 12.4 ft/min or 0.207 ft/sec at 5 gpm, or 0.414 ft/sec at 10 gpm. This is slow flow. It is just slightly higher than typical water flow velocities motivated by natural convection with modest temperature differentials. However, because flow is constricted by the fluted channels of the bushings, local flow velocity across the Cutless bushings is faster than that estimated for the annular space between bushings.

When there is gland water, water in the clearance between the shaft and the Cutless bushings can form a typical lubrication wedge. This wedge also further cushions and dampens lateral motion of the pump shaft. The surface speed of the pump shaft at 1180 rpm is 11.26 ft/sec.

The 410 hardened stainless steel shaft has a hardness of about 225 BHN. Consequently, it has a tensile strength of about 106,000 psi and a yield strength of about 92,000 psi (5). At 250 degrees F, the 410 stainless steel shaft does not significantly lose material strength.

## Assessment

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 river. The level in the enveloping tube will not match that of the river because the pressure at the bottom hub of the impeller, that is, at the "eye" of the impeller, will be slightly less than the ambient pressure at the same elevation elsewhere in the "E" bay. When the pump is operating at full load, this decrease in pressure will be about 0.75 psi. This figure is based upon the loss of pressure head at that elevation due to increased flow velocity near the inlet of the pump.

Consequently, the water level in the enveloping tube will be about 1.73 feet lower than the level of the river. Assuming that the river is at a "typical" elevation of perhaps 880', then the lower half of the enveloping tube will still have water in it. At least four of the Cutless bushings will still have water for lubrication.

The upper six or seven bushings will eventually become dry and will lose the wedge of water between the rotating shaft and the surface of the Cutless bushings. Thus, intermittent dry contact between the bushing and the pump shaft will occur.

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 (6). This is a verified, quality control step in the assembly of the pump that is required to be witnessed and verified (6). This is important because it ensures that the pump has no significant points of binding or friction. Further, when this is done, 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 at first soften, and then as heating progresses further, it become 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. This is, of course, why overheated, "cooked" nitrile rubber exhibits deep cracking.

If the temperature of nitrile rubber exceeds 400 degrees F, the nitrile rubber will have lost so much material strength that frictional contact with the shaft will easily tear away material at its surface (2,3,4). At 400 degrees F, the hardened 410 stainless steel's material properties will not be significantly affected (5). This process will continue until the inside diameter of the bushings is sufficiently wallowed out to match the total lateral motion of the shaft.

It has been 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 can not contact all the rubber in the bushing, that is, the shaft can not be grabbed on all sizes by the rubber like the clinching action of a prony brake. 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.

Thus, in order for the shaft to be seized by the bushings, a lateral force must press the shaft continuously into the rubber. The lateral motion caused by centerline eccentricity or mass distribution eccentricity, however, is sinusoidal. It does not press the shaft continually into the bushing in one spot. Instead, it "bangs" around in the hole as the shaft rotates. As noted before, the bushing acts like a type of internal bumper. Actual contact between the shaft and the bushing is, therefore, intermittent not continuous.

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.

This fact was demonstrated in December 2001, when the impeller and bowl of the "D" service water pump were jammed together sufficiently to prevent rotation of the impeller. The torque of the motor completely twisted off the 410 hardened stainless steel coupling.

If the lateral force on each bushing, when it is dry, were about 100 pounds, which is grossly high, the frictional force between the shaft and each bushing will be 50 pounds. This will create a frictional torque drag of 55 in-lbs or 4.6 ft-lbs at each bushing. Since perhaps six or seven of the bushings will eventually become dry, this is an increase in torque of 32.2 ft-lbs. At running load, the pump motor driver is capable of developing 1,334 ft-lbs of torque. Thus, the drag of six dry bushings will "steal" about 2.4% of the motor's torque. The motor can easily handle this.

Typical vibration measurements on the service water pumps indicate that the vibrational velocity is about 0.1 or 0.2 inches per second. The service water pumps are allowed to have a vibration level of about 0.7 in/sec before they have to be serviced (7).

At 0.1 in/sec, the peak-to-peak displacement is about 0.0008 inches. At 0.7 in/sec, the peak-to-peak displacement is about 0.0056 inches.

The maximum allowable diametrical clearance between the shaft and the bushings is 0.026 inches. The initial clearance can be as tight at 0.006 inches, but would normally be around 0.010 or 0.012 inches.

If the pump were allowed to operate until the 0.7 in/sec vibration level were reached due to sideways wobble, the vibrational "shake" pattern of the shaft still fits inside the diametric clearance of the bushing.

If vibrations are allowed to continue to increase significantly higher than 0.7 in/sec, the bounding limitation appears to be the vibrational tolerance of the lower bearing in the driver motor. Increased vibrational levels in the lower bearing of the motor-driver can cause its life to shorten. If the induced vibrations are sufficiently severe to cause high radial loading, the bearing will degrade, become damage, and eventually fail. This is the most severe scenario.

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 later when gland water is restored.

Due to conduction and convections effects in the shaft, the shaft will not be affected by this heating. Hardened 410 stainless steel will not warp or be metallurgically affected by localized heating until temperatures exceed 1200 F for an extended period (5).

The packing on the service water pumps is not excessively tightened to control leakage. In fact, it is the practice at CNS to allow the packing to generously leak so that an operator can visually check gland water flow to the pump.

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.

## Vibration Check

A simple check was made of some of the vibration characteristics of the pump to determine if any harmonics might cause undue excitation of the pump if bushings were lost due to damage. A simple, undamped model of a continuous shaft that was pinned, but not clamped at the ends was employed. The calculations are appended.

It was found that at the normal rotational speed, the loss of bushings does not cause the shaft to suffer harmonic vibration problems induced by the motor.

This is further confirmed by experience. Non-linear increases in vibrations with respect to bushing clearance increases have not been noted to occur.

## Conclusion

Based upon the preceding assessment, it is concluded that a temporary loss of gland water for 90 minutes will not severely damage or incapacitate the pump.

Some damage to the bushings may occur, especially those bushings near the center of the pump shaft, and some damage to the upper packing may occur. The damage 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.

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.

## Corroborative Data and Analysis

Johnson 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 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) for an additional 48 hours.*

Please note that in his report, Mr. Cugal regularly refers to the Cutless bushings as bearings. Technical nomenclature in this area is not standardized, and various terms are used that are interchangeable. A copy of the Cugal report is appended.

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 Johnson Pump Company. The final report, which was authored by Nirmal Ganagra and checked by Lanka Pannila, P.E., concluded the following on page 52.

> *A rotordynamic model of the pump for calculating the lateral eigenvalues (natural frequencies) and their corresponding eigenvectors (mode shapes) was created using XLRotor software*
>
> *Results indicate an enclosing tube mode within about 4.5% of the running speed. At this mode, the tube is in phase with the shaft throughout its length in the normal water flush condition, and hence, may not be harmful to the lineshaft bearings.*
>
> *No other modes exist within +/- 15% of the running speed of 1180 RPM for all the cases.*
>
> *The effect of doubled clearances at the bearing* [bushing] *and wear ring locations is to reduce the lateral natural frequencies by a small amount, which, however, precludes any harmful effects.*
>
> *Due to the assumptions made and the possibility of various possible kinds of excitations and imperfections in real life like misalignment of the shafts, concentricity issues with the shafting, excessive rotor imbalance, etc., the results of any analysis should be treated with caution, and be used to get an idea of the possibilities rather than to predict the results.*

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. Anecdotal information from various plants has been obtained by both CNS and Mr. Cugal that indicates service water pumps of the type used by CNS have successfully operated for short periods of time without gland water. Unfortunately, official documentation of this type of success or non-failure is scarce.

The following related OE report is quoted directly from the INPO web database. It is noteworthy that the service water pumps at Farley are the same type and have the same design as those used at CNS with a notable exception: they do not have balance holes in the impeller. The lack of balance holes means that the enveloping tube will be replenished with flow in the reverse direction when gland water is lost. This OE is cited because it is one example of where there was no problem, but the event was reported in a database because of regulatory requirements.

| | |
|---|---|
| Event Title: | Both Service Water Lubrication and Cooling Water Pumps Inoperable |
| Event Summary: | On February 7, 2000, at 1430, it was determined that for approximately the previous 11 hours, Farley Nuclear Plant Unit 2 may have been operating at 100 percent power in a condition that could have prevented fulfillment of a safety function for removal of shutdown decay heat. On February 6, 2000, at 0257, the B train service water (SW) lube and cooling booster pump failed. No technical specification limiting condition was identified. On February 7, 2000, at 0329, an A train diesel generator (DG) was removed from service for planned maintenance. At this time both trains of SW could have failed to perform their intended function should a dual unit loss of off-site power (LOSP) event have occurred. HOWEVER, BASED ON THE PUMP CONDITIONS THAT EXISTED DURING THIS TIME PERIOD, THE SW PUMP VENDOR CONCLUDED THAT THE PUMPS SHOULD HAVE BEEN CAPABLE OF OPERATING FOR A MINIMUM OF 24 HOURS FOLLOWING A LOSS OF EXTERNAL LUBE AND COOLING WATER. Since the total time period that the booster pump and the DG were both inoperable was approximately 12.5 hours (11 hours prior to identification and 1.5 hours subsequent to identification), there would have been at least one train of SW available at all times. The DG was returned to service at 1605 on February 7, 2000, thereby restoring the functionality of the A train SW system. The B train lube and cooling booster pump was returned to service at 1303 on February 8, 2000. The cyclone separator, a nonsafety-related source of filtered lube and cooling water supply to the SW pumps, remained operable throughout this event. The SW pumps would have been affected only if a dual unit LOSP had occurred. If an LOSP had occurred, the lube and cooling water flow would have come from service water leakage through the shaft packing. This which would have increased the pump bearing wear rate, but would not have resulted in near term pump failure. The cause of this event was a potentially inadequate procedure, in that the procedure identifying necessary attendant plant equipment did not specify the booster pumps as necessary attendant equipment for the Unit 2 SW pumps. FNP has not considered the booster pumps to be necessary attendant equipment for a number of years. This issue was examined by |

NRC and dispositioned by FNP during the 1993 service water system operational performance inspection (SWSOPI). However, a discrepancy between the functional system description and the SWSOPI results has been identified. Subsequent evaluation has determined that the booster pumps are necessary attendant equipment. The procedure has been revised to include the SW booster pumps as necessary attendant equipment for Unit 2 SW pumps. Licensed and on-shift operations personnel have been sent notifications of this procedure change. This event is not significant because lubrication and cooling of the service water pump bearings can be provided by the normal shaft packing leakoff. This event is NOTEWORTHY because the SW lube and cooling booster pumps, which provide a safety-related source of filtered water to the service water pump bearings, were both inoperable for a period of 11 hours.

| | |
|---|---|
| Event Number: | 364-000207-1 |
| Event Date: | 02/07/2000 |
| INPO Change Date: | 06/13/2000 |
| Unit: | 364, Farley 2 |
| NSSS Vendor: | Westinghouse Electric |
| NSSS Type: | PWR - Pressurized Water Reactor |
| Country: | USA |
| INPO Significance: | Noteworthy Event |
| Initial Plant Condition: | Steady State Power, 100% Power |
| Event Descriptor: | Outside License Basis |
| Event Descriptor: | Procedure Inadequacy |
| Event Descriptor: | AC |

Identified Component/System Failures:

| Component | System | Failure Consequence | Equipment Causal Factor |
|---|---|---|---|
| PUMP | WAD | Initiated the Event | Other Equipment Failure |

| | |
|---|---|
| Keywords: | BEARING, ESSENTIAL SERVICE WATER, SERVICE WATER |
| Primary Source Document: | LICENSEE EVENT REPORT, 364-00001, 03/03/2000 |
| Secondary Source Document: | LICENSEE EVENT REPORT, 364-00001-1, 04/05/2000 |
| Secondary Source Document: | LICENSEE EVENT REPORT, 364-00001-2, 06/05/2000 |

An inquiry was made within CNS as to whether a previous event had occurred in which a Cutless bushing was lost due to seizing on the shaft. The following email was received from the pump component engineer.

> *Information from interviews with maintenance personal crew leads and mechanics are consistent in that there have been no catastrophic failures of service water pump cutless bearings.*
> *There has been one instance where the rubber was ejected from the housing and remained on the shaft. This was infant mortality due to failure to adhere to the housing. The pump operated normally with no abnormal vibration noted. The condition was isolated and has not recurred. There have been other instances of a sliver of the rubber missing and others with more than normal wear but these do not constitute bearing failures.*
>
> *Stephen L.Phillips*
> *Maintenance Support Engineering, Rotating Components*
> *Equipment Reliability Department*
> *Cooper Nuclear Station, Nebraska Public Power District*
> *Brownville, NE, 68321-0098*
> *402-825-2959, Fax402-825-5033, Email slphill@nppd.com*

The relevence of the above is that despite the fact that the rubber bushing material rolled up inside the bushing cylinder in an abnormal position, and the laterial support of the bushing was removed, no delcterious effects on the operation of the pump occurred or were noticed.

An OE report where a Cutless bushing caused seizing of a service water pump was noted in the literature. It is quoted in full below.

```
"Tran, Hai (DAEC)" <tranh@inponn.org> wrote in message
news:<30gr9vsqsqa1q839210t8n233r779pjbko@4ax.com>....
> **** RESTRICTED AND CONFIDENTIAL ****
>
> Subject: OE15991 - (Update to OE14428) - Emergency Service Water Pump
> Tripped On Thermal Overload During Surveillance Testing
>
> Abstract:
>
> During a surveillance test on 6/23/02, the "B" Emergency Service
Water
> (ESW) Pump tripped the timed overcurrent (thermals) on its power
> supply breaker due to excessive drag on the pump shaft.  This drag
was
> caused by swelling of the pump bowl bearings comprised of an
> elastomer, which is now considered an inappropriate material for this
> application.
>
> Reason for Message:
>
```

> To update the preliminary OE14428 report and share our experience of
> the ESW pump failure.
>
> Event Date:.............June 23, 2002
> Unit Name:..............Duane Arnold Energy Center
> NSS/A-E:................GE/Bechtel
> Turbine Manufacturer:...GE
>
> Maintenance Rule Applicability: Yes
>
> Component Information (as applicable):
> Manufacturer:.........Johnston Pump Company
> NSS/A-Model Number:....5 Stage, 12DC
> Part Number:..........NB6701
>
> Description:
>
> On June 23, 2002 the "B" ESW Pump breaker tripped on timed
overcurrent
> while the "B" ESW Pump was running to support a "B" Stand-by Diesel
> Generator (SBDG) operability test. The pump had been running for
> about 90 minutes at the time that it tripped. A Technical
> Specification (TS) Limiting Condition for Operation (LCO) for having
> one ESW Subsystem inoperable was entered. This LCO required the
> subsystem to be returned to operable status within 7 days or the
> reactor would be required to shutdown.
>
> A troubleshooting inspection of the breaker found that the timed
> overcurrent trip (thermals) had caused the "B" ESW Pump trip. Only
> minor problems were found in the breaker during this inspection.
> There were no causes found for an overcurrent trip. The "B" ESW Pump
> motor was meggared with acceptable results and connections within the
> breaker were checked for excessive resistance with no problems found.
> A decision was made to restart the "B" ESW Pump and monitor the motor
> current at the breaker.
>
> The "B" ESW Pump was restarted on June 23rd. Starting current and
> running current were monitored. The starting current was 609 amps,
> which is within the expected range of 5 to 7 times normal running
> current. The observed running current was 115 amps, which is
slightly
> lower than the nameplate current of 118.3 amps. This current was
> observed with the same flowrate on the pump that was on it when it
had
> tripped earlier in the day.
>
> The Operations Department did observe that this running current was
> about 10 amps higher than they normally observed on the control room
> current meter for these flow conditions.
>
> On June 23rd after the "B" ESW Pump had run for 71 minutes, it again
> tripped on timed overcurrent.
>
> On June 24th additional troubleshooting plans were prepared to re-run

> the "B" ESW Pump with a recorder attached to the pump breaker so that
> the current at the time of pump trip could be captured. Due to the
> observations made on June 23rd, a timed overcurrent trip device
> problem was still suspected as the cause of the pump trips. Prior to
> starting the pump for the third time, the pump shaft break-away
torque
> was measured to ensure that the pump was not bound up. When the
> torque was checked, it was found that the pump shaft would not move
> even with 100 ft-lbs of torque applied. At this point it was
> determined that the "B" ESW Pump would be replaced.
>
> On June 25, 2002, the "B" ESW Pump was replaced. When the pump was
> removed, a visual and camera inspection was made. No obvious reason
> for the pump to be bound up was found. Also on June 25th, the "B"
ESW
> Pump breaker thermal overloads were checked for proper operation.
The
> overcurrent trip setpoint was found to be within limits per
procedure.
>
> On June 26, 2002, the "B"ESW Pump was declared operable after
> completion of post maintenance testing. The plant exited the TS LCO
> at this time.
>
> On July 2, 2002, the "B"ESW Pump was disassembled at the pump vendor
> factory (Johnston Pump Company) in Chattanooga Tennessee to determine
> the cause of the excessive drag on the pump shaft. The bearings were
> observed to be tight and were forced off the shaft. The bearings are
> a "Cutless" Marine type of bearing that uses an elastomer as a
bearing
> surface. The bearings are required to have clearance with the shaft.
> However, measurements after disassembly showed that the free inside
> diameter of the bearings were less than the shaft diameter.
>
> Causes:
>
> The ESW Pump tripped the timed overcurrent (thermals) on its power
> supply breaker due to excessive drag on the pump shaft. This drag
was
> caused by swelling of the pump bowl bearings comprised of an
> elastomer, which is now considered an inappropriate material for this
> application. Two contributing causes were identified (1) allowance
> was not made in the original design for material swelling and (2)
> unanticipated consequences from a change in the pump shaft to a much
> smoother surface in 1992. This smooth surface did not wear away the
> elastomer bearing as it swelled.
>
> Corrective Actions:
>
> To ensure that the installed ESW Pumps did not have the same problem,
> they were verified to have adequate as-built clearances and to not
> have any pump shaft drag when coasting down after operation. Other
> corrective actions include:
>

```
> * Complete a design change to specify an appropriate material
> for the pump bearings that is not subject to excessive swelling.
>
> * Change the ESW Pump surveillance test procedure so that in
> addition to the pump shaft coast down being monitored, the amount of
> current that the pump draws is monitored and recorded during each
> surveillance.
>
> * Remove the currently installed ESW Pumps and replace the
> bearings with appropriate material.
>
> Safety Significance:
>
> The safety consequences of this event were minimal.  Although the "B"
> ESW Pump failed, the "A" ESW Pump was fully operable and would have
> provided adequate cooling to allow operation of the "A" SBDG and the
> "A" Loop Emergency Core Cooling Subsystems in the event of a design
> basis accident.
>
> Additionally, the "B" ESW Pump had been run for several hours only a
> few weeks before this failure and therefore it can be assumed that
the
> pump failure did not go undetected for any great length of time.
>
> Subject: OE15991 - (Update to OE14428) - Emergency Service Water Pump
> Tripped On Thermal Overload During Surveillance Testing
>
> Information Contact:
> Jim Swales - System Engineer
> Phone:  (319) 851-7686
> E-mail:  James.Swales@nmcco.com
```

The significance of the above OE report is the corrective action adopted by Duane Arnold to ensure that the pump does not have excessive drag. In essence, to protect against future problems, the Duane Arnold station adopted an "anti-drag" procedure similar to that which is already in place at CNS (6). This OE is, therefore, cited to show the significance of this procedural step in eliminating the problem of misalignment vis-à-vis rubber bushings seizing. Further, the corrective action cited by Duane Arnold to guard against misalignement occurring during service by checking motor current has been routinely done by the service water system engineer, and has been required on several surveillance procedures at CNS for some time. Thus, as previously noted, measures to ensure that there is good concentricity and that the bushings do not bind the shaft are already in place at CNS.

References

1. *Standard Handbook for Mechanical Engineers,* Baumeister and Marks, Seventh Edition, page 6-199.
2. http://www.reemrubber.com/NitrileDataSheet.htm
3. http://www.fibrematerials.com/rubber.htm
4. http://www.baxterrubber.com/buna-n.html
5. Working Data - Carpenter Stainless Steels, 1973, page 25.
6. CNS Procedure 7.2.15, step 8.9, "(QC Witness) Manually rotate pump to ensure it turns freely.
7. CNS Procedures 6.1SW.101 and 6.2SW.101, acceptance criteria for vibrations.