NRC Form 366 (9-83)

U.S. NUCLEAR REGULATORY COMMISSION
APPROVED OMB NO. 3150-0104
EXPIRES: 8/31/88

LICENSEE EVENT REPORT (LER)

FACILITY NAME (1)	DOCKET NUMBER (2)	PAGE (3)
South Texas, Unit 1	0 5 0 0 0 4 9 8	1 OF 0 7

TITLE (4) Auxiliary Feedwater Pump Shaft Sleeve Failure Due To Stress Corrosion Cracking/ Hydrogen Embrittlement

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAMES	DOCKET NUMBER(S)
0 5	1 2	8 8	8 8	0 3 2	0 0	0 6	1 3	8 8	South Texas, Unit 2	0 5 0 0 0 4 9 9
										0 5 0 0 0

OPERATING MODE (9)	5
POWER LEVEL (10)	0 0 0

THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more of the following) (11)

20.402(b)	20.405(c)	50.73(a)(2)(iv)	73.71(b)
20.405(a)(1)(i)	50.36(c)(1)	X 50.73(a)(2)(v)	73.71(c)
20.405(a)(1)(ii)	50.36(c)(2)	50.73(a)(2)(vii)	X OTHER (Specify in Abstract below and in Text, NRC Form 366A) 10CFR21 10CFR50.55(e)
20.405(a)(1)(iii)	50.73(a)(2)(i)	50.73(a)(2)(viii)(A)	
20.405(a)(1)(iv)	50.73(a)(2)(ii)	50.73(a)(2)(viii)(B)	
20.405(a)(1)(v)	50.73(a)(2)(iii)	50.73(a)(2)(x)	

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER	
	AREA CODE	
Charles Ayala - Supervising Licensing Engineer	5 1 2	9 7 2 - 8 6 2 8

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO NPRDS
B	B A	P	B 2 6 0	Y					

SUPPLEMENTAL REPORT EXPECTED (14)		EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
YES (If yes, complete EXPECTED SUBMISSION DATE)	X NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately fifteen single-space typewritten lines) (16)

On February 28, 1988, with Unit 1 in Hot Standby (Mode 3), an Auxiliary Feedwater (AF) Pump failed its performance test. Subsequent inspection of the pump internals revealed significant damage, including a split in the center shaft sleeve (part of the center-stage bushing assembly). The pump was replaced with a similar pump from Unit 2, which is currently under construction. The replacement pump was tested and declared operable on March 7, 1988. On May 5, 1988, an inspection of a Unit 2 AF pump revealed similar damage. On May 12, 1988, it was determined that the failure mechanism could, if left uncorrected, affect redundant AF pumps, and the NRC was notified. An investigation into the cause of the sleeve splitting determined the root cause to be stress corrosion cracking/hydrogen embrittlement of the sleeve material. The pump sleeve material will be replaced with a softer stainless steel which is not susceptible to stress corrosion cracking/hydrogen embrittlement. Until this modification can be completed, the Unit 1 pumps will be tested weekly for operability. This condition is reportable under 10CFR50.73(a)(2)(v), 10CFR50.55(e) and 10CFR21.

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NL.88.141.03

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

DESCRIPTION OF EVENT:

On February 28, 1988, with the unit in Hot Standby (Mode 3), the turbine driven Auxiliary Feedwater (AF) pump #14 (Train D) failed its performance test. Speed was steadily dropping, and continued to drop even after adjustments to the governor were performed. At 2200 hours on that day, during performance monitoring, the pump outboard bearing cap was noted to be extremely hot. No excessive vibration was observed during the performance monitoring. The pump casing was opened, and an inspection of the pump showed that the center shaft bushing next to the 5th stage impeller and the shaft throttle bushing next to the 6th stage impeller (at the outboard end of the pump) were damaged. The damage observed at the center shaft location included a split in the center shaft sleeve, and the sleeve appeared to have sheared off the common key with the 5th stage impeller. The following damage was observed at the throttle bushing location: the shaft sleeve had seized (or friction welded) to the bushing, the sleeve was split axially at the keyway (with the key still in place), and the bushing outside surface was discolored almost black, with heavy abrasion marks and metal deformation. The pump was removed and replaced with a similar pump from Unit 2, which is under construction. A spare rotating element was installed in the replacement pump casing. The pump was tested and declared operable on March 7, 1988. The damaged pump was shipped back to Bingham International (formerly Bingham Willamette), the pump manufacturer. Bingham removed the damaged parts from the rotating element, and samples of the bushings and sleeves were sent to Bechtel Material and Quality Services (M&QS) for a failure analysis. M&QS completed the failure analysis and sent the results to STP on April 26, 1988. The report indicated that the root cause of the failure was due to stress corrosion cracking/hydrogen embrittlement of the sleeves. The corrosion progressed until cracks developed and friction forces were generated sufficient to degrade pump performance.

Through discussions with Bingham, it was decided to change the sleeve material to a material which is not susceptible to stress corrosion cracking. To pursue this rework, the Unit 2 motor-driven rotating elements were removed and prepared for shipment to Bingham. On May 5, 1988, prior to shipment, an inspection was performed and the following damage noted: one rotating element (pump #23) exhibited a longitudinal crack in the center shaft sleeve, which appeared to be very similar to the damage of the Unit 1 turbine driven pump; one rotating element (pump #22) exhibited a crack in the wear ring for the 6th stage impeller hub at the rotating pin. The wear rings are made from the same material as the shaft sleeves.

On May 12, 1988, a determination was made that the failure mechanism could, if left uncorrected, affect other redundant AF pumps, and the NRC was notified at 1501 hours. The unit was in cold shutdown (Mode 5) at that time for an unrelated maintenance outage.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

DESCRIPTION OF EVENT (Cont.):

The Auxiliary Feedwater System provides feedwater for the removal of reactor core decay heat when the main feedwater supply is not available. In addition, the system is designed to function during plant startup to fill the steam generators and maintain the required water level. The system consists of four separate trains. Three of the trains (A, B, and C) use motor-driven pumps and valves powered from essential AC power sources. The fourth train (D) utilizes a steam turbine driven pump and valves powered from essential DC power sources. With the exception of the driver sources, the pumps are identical with relation to configuration and materials used in the pumps.

The pumps are Bingham model 4x6x9 C MSD eleven stage, single suction, double volute, with a horizontal split casing (see Figure 1). The configuration of the impellers is called an opposed impeller arrangement. The first five impellers face in one direction, and the remaining six impellers face in the opposite direction. In order to center the impellers and shaft, a center stage bushing and a throttle bushing assembly are utilized. Both assembly locations use a rotating sleeve and stationary bushing design. The sleeves are shrunk-fit and keyed to the shaft. The material used for the sleeve is AISI 420 stainless steel hardened to 450-525 HB.

The failure analysis performed by the M&QS personnel included the following examinations: visual, scanning electron microscope, hot acid etch, hardness test, metallographic, and surface chemical. Through these examinations it has been determined that the sleeve material meets design requirements for material type, heat treatment and hardness requirement.

Hardened steels, including chromium stainless steels such as type 420 stainless steel, are susceptible to stress corrosion cracking and hydrogen embrittlement. Although fine differences exist between stress corrosion cracking and hydrogen embrittlement cracking, it is often not possible to distinguish which one is responsible for metal cracking in actual failures. Stress corrosion cracking is a result of a combined action of a static tensile stress and a suitable corroding environment, which could have existed sometime in the auxiliary feedwater system. Hydrogen embrittlement is produced by the presence of excessive amounts of hydrogen. The source of the hydrogen may include corrosion by-products as well as residual hydrogen from steelmaking, acid cleaning and plating. The evidence from the examinations performed indicates that the cracking in the sleeves was caused by stress corrosion cracking, hydrogen embrittlement, or both; and that the cracking is intergranular.

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TEXT (If more space is required, use additional NRC Form 366A's) (17)

DESCRIPTION OF EVENT (Cont.):

The failure analysis indicates that the most probable scenario for the failure event is as follows. The splits in the sleeves came first, independent of one another. The increase in diameter due to the splits caused the frictional heating. The 0.053 inch gap, the measured gap at the split of the center shaft sleeve, is equivalent to an increase in diameter of 0.017 inch, which is more than the design clearance between the sleeve and the shaft center stage piece. It is reasonable, therefore, to believe that the initial friction between them was sufficiently high to shear the key. Subsequently, the shaft center sleeve rotated around the shaft inside the center stage piece, cutting into the 5th stage impeller hub. The keyway length in the throttle bushing assembly sleeve is much longer than that in the shaft center sleeve. Therefore, the key in the throttle sleeve remained in place, overcoming the friction force that developed as a result of the split. Instead, the friction between the throttle sleeve and the throttle bushing caused intense heat which resulted in melting of the metals. Some molten metal was extruded and welded the sleeve and bushing together. This was the source of the heat which was observed at the throttle bearing cap during performance testing.

CAUSE OF EVENT:

Based on the above information, the immediate cause of the pump failure was determined to be friction and internal damage to the pump caused by splitting of the shaft sleeves. This splitting was induced by stress corrosion cracking/hydrogen embrittlement of the shaft sleeve material. The primary root cause was the use of a material that is susceptible to stress corrosion cracking/hydrogen embrittlement.

ANALYSIS OF EVENT:

FSAR Chapter 15 Analysis requires at least two Auxiliary Feedwater pumps to feed two Steam Generators to meet cooldown conditions. Safety analyses are based on the use of two Auxiliary Feedwater pumps, and the Technical Specification action statements were developed to maintain those requirements. STP Unit 1 has four Auxiliary Feedwater pumps, and all are covered by the Technical Specifications.

An Unreviewed Safety Question (10CFR50.59) Evaluation was performed and submitted to the NRC on May 13, 1988. It should be noted that stress corrosion cracking/hydrogen embrittlement is time dependent. The stresses on the sleeve are largely residual due to the heat treatment and shrink fit process. Operation of the pump has a negligible effect on the corrosion rate. Also, since the corrosion occurs at a rate dependent upon other variables such as residual stresses in the sleeves, local chemistry, exposure time in the water, and chemical properties for the materials; multiple pump failures at the same time would not be a credible event. Thus, a failure of one pump does not imply immediate failure of all the pumps, nor does it imply that operability of the other pumps is compromised. Therefore, at no time during the event was there an adverse effect to the safety of the plant or the public.

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ANALYSIS OF EVENT (Cont.):

Corrosion pitting is the precursor to stress corrosion cracking. The pitting is more likely to initiate when subjected to low pH and high oxygen levels in the water. These conditions typically exist during the early startup phases. When normal operational chemistry requirements are implemented the water chemistry requirements change to a higher pH and low oxygen levels, thereby reducing the probability of initiating corrosion pitting. In Unit 1, normal operational chemistry was initiated in September, 1986. Based on discussions with the Bechtel M&QS group, the crack propagation rate is estimated to be in the range of 50 to 500 hours. Thus, it would be expected that if a crack condition existed it would have already been detected by pump performance degradation, or that it was not affecting pump performance.

If this condition had remained undetected, a situation could have evolved which could have resulted in the loss of more than one AF pump and, eventually, the loss of a safety function. As such, it is reportable under 10CFR50.73(a)(2)(v) and 10CFR21, and is reportable under 10CFR50.55(e) for Unit 2.

CORRECTIVE ACTIONS:

1. The sleeve and wear ring material on the pumps will be changed to Type 410 stainless steel hardened to 250-300 HB. This material has been used successfully in earlier models of this type of pump. For compatibility, the bushing material will be replaced with ASTM A436 Ni-resist Type 2. This change will eliminate susceptibility to stress corrosion cracking/hydrogen embrittlement as experienced with the harder material presently used, and thereby eliminate this problem.

    a. The rotating assemblies have been removed from the Unit 2 pumps and sent to Bingham for modification as described above. An on-site spare rotating assembly has also been sent for modification. It is anticipated that the first modified rotating assemblies will be received by June 30, 1988. They will be installed in the Unit 1 AF pumps at the earliest opportunity thereafter.

    b. Modified assemblies will be installed in Unit 2 prior to Unit 2 entering Mode 3.

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CORRECTIVE ACTIONS (Cont.):

2. To provide a higher assurance of operability until the rotating assemblies can be replaced, the Unit 1 AF pumps will be operated once a week as plant conditions permit. The flow rates will be compared to the surveillance requirements for operability. The motor current amperage on the motor-driven pumps will also be monitored for sudden increases in amperage which could indicate pump degradation. The AF pumps (motor and steam driven) will also be observed during coast down. The pumps should coast down to a smooth and uniform stop with no abrupt stoppage observed. Abrupt stoppage may be a sign of pump degradation. If surveillance results and evaluation reveal evidence of pump degradation due to shaft sleeve failure, the affected pump(s) will be declared inoperable and the appropriate Technical Specification action statement will be applied. If plant conditions exist such that the pumps cannot be operated on a weekly basis, the tests will be performed as soon as plant conditions permit. This enhanced surveillance testing will continue until the reworked assemblies are installed as described in Corrective Action 1.a above.

ADDITIONAL INFORMATION:

The enhanced surveillance testing discussed above provides continued demonstration that the Auxiliary Feedwater pumps are operating as designed. The results to date indicate that the pumps are within the expected flow range and coast down times for an acceptable pump. The coast down observations also indicate that the pumps roll to a smooth stop with no abrupt stoppage. Amperage data has been compared to the original start-up test data and there are no significant changes in the readings.

It has been learned that Palo Verde Nuclear Generating Station had a failure similar to the one at South Texas Project. Through communications with Palo Verde it was learned that they had already conducted a Nuclear Plant Reliability Data System (NPRDS) search to determine if this failure mechanism has been experienced at other utilities. There were no NPRDS reports of similar failures.

HL&P has submitted additional information on this subject in a letter from G. E. Vaughn to the USNRC, dated May 13, 1988 (ST-HL-AE-2657).

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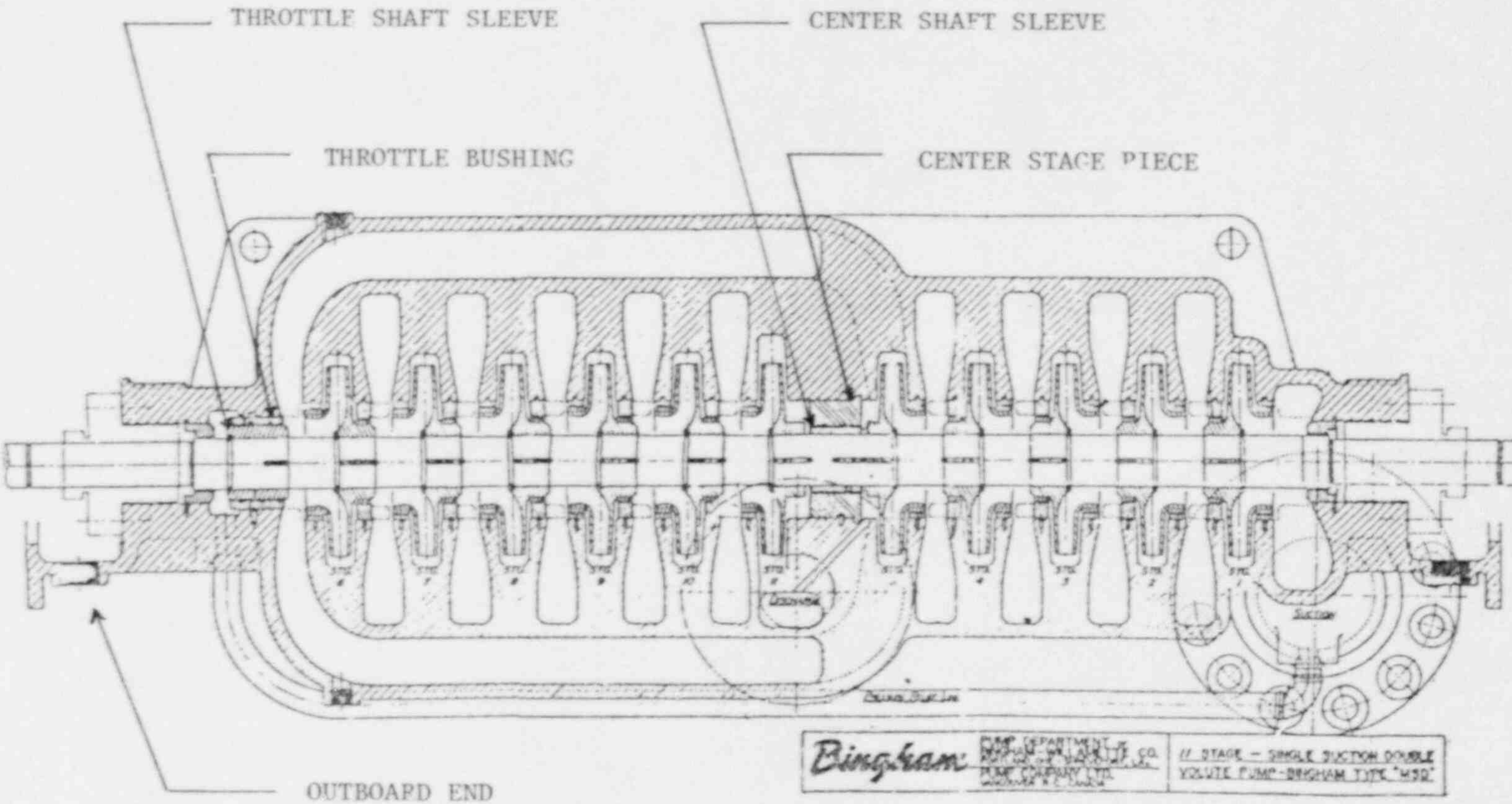

AUXILIARY FEEDWATER PUMP

Figure 1

The Light company
Houston Lighting & Power

P.O. Box 1700 Houston, Texas 77001 (713) 228-9211

June 13, 1988
ST-HL-AE-2671
File No.: G26
10CFR50.73
10CFR50.55(e)
10CFR21

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

South Texas Project Electric Generating Station
Units 1 and 2
Docket Nos. STN 50-498 and STN 50-499
Licensee Event Report 88-032 Regarding
Auxiliary Feedwater Pump Shaft Sleeve Failure
Due to Stress Corrosion Cracking/Hydrogen Embrittlement

On May 12, 1988, Houston Lighting & Power Company (HL&P) notified the NRC of Auxiliary Feedwater Pump damage due to stress corrosion cracking/hydrogen embrittlement of the pump shaft sleeves. If this condition had remained undetected it could have resulted in inoperability of the pumps. An enhanced surveillance program has been initiated until the pump rotors are replaced. The event did not have any adverse impact on the health and safety of the public. Pursuant to 10CFR50.73, HL&P is submitting the attached Licensee Event Report (LER-88-32). This Licensee Event Report also satisfies the reporting requirements of 10CFR21 and 10CFR50.55(e) for Unit 2.

HL&P has submitted additional information on this subject in a letter from G.E. Vaughn to the USNRC, dated May 13, 1988 (ST-HL-AE-2657).

If you should have any questions on this matter, please contact Mr. C.A. Ayala at (512) 972-8628.

G. E. Vaughn
Vice President
Nuclear Plant Operations

GEV/RSS/nl

Attachment: Licensee Event Report 88-032 Regarding
Auxiliary Feedwater Pump Shaft Sleeve Failure Due
to Stress Corrosion Cracking/Hydrogen Embrittlement

IE22
1/1

cc:

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