The Light company
Houston Lighting & Power

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

May 13, 1988
ST-HL-AE-2657
File No.: G20
10CFR50.36

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

South Texas Project Electric Generating Station
Unit 1
Docket No. STN 50-498
Auxiliary Feedwater
Pump Shaft Sleeve Failures

A discussion was held between our staff and NRC Region IV and NRR staff personnel regarding the above subject on the morning of May 13, 1988. The attached safety evaluation has been updated and contains Houston Lighting & Power's justification for continued operation which was described during the discussion. Per the NRC's request a copy is attached herein.

We have initiated an aggressive expediting program with Bingham International to obtain modified rotating assemblies as part of our long term corrective measures for the Unit 1 Auxiliary Feedwater (AFW) pumps. Bingham is handling STPEGS's refabrication as their top priority. The expedited schedule for delivery of the first modified assembly targets receipt in mid-June of this year. We expect to be able to complete installation of the assemblies in Unit 1 at the earliest opportunity thereafter.

Additionally, should the results of our enhanced weekly surveillance program, described in the attachment, reveal evidence of degradation of an AFW pump due to shaft sleeve failure we intend to take immediate actions to initiate plant shutdown and promptly re-evaluate AFW system acceptability.

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

Very truly yours,
G.E. Vaughn by W.H. Kinsey
G. E. Vaughn
Vice President
Nuclear Plant Operations

GEV/CAA/nl

Attachment: STPEGS Unreviewed Safety Question Evaluation
#880074 Dated May 13, 1988, Revision 1

A001
1/1

NL.88.134.01

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ATTACHMENT IP-3.20Q-4

UNREVIEWED SAFETY QUESTION EVALUATION FORM
(Page 1 of 4)

Unreviewed Safety Question Evaluation # 880074 REV 1 Date Assigned 5/3/89

☐ Procedure Change ☐ Plant Modification ☒ Other

Originating Document: FAILURE ANALYSIS REPORT, PR 880086 USQ 880074 REV 0 Rev. # _____

TITLE: FAILURE ANALYSIS OF SHAFT SLEEVES IN AN AUXILIARY FEEDWATER PUMP

DESCRIPTION: THE REPORT, WHICH DOCUMENTS THE RESULTS OF ANALYSIS FOR THE FAILURE OF THE TURBINE DRIVEN AUXILIARY FEEDWATER PUMP #1A, INDICATES THAT THE ROOT CAUSE OF FAILURE IS STRESS CORROSION CRACKING/HYDROGEN EMBRITTLEMENT IN THE SLEEVE.

A. 1. Does the subject of this evaluation increase the probability of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the safety analysis report? ☐ YES ☒ NO

Bases: STRESS CORROSION CRACKING/HYDROGEN EMBRITTLEMENT IS TIME DEPENDENT AND OCCURS BASED ON OTHER VARYING FACTORS: RESIDUAL STRESSES, LOCAL CHEMISTRY, EXPOSURE TIME IN WATER AND CHEMICAL PROPERTIES. BASED ON ALL THESE FACTORS 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 OTHER PUMPS, NOR DOES IT IMPLY OPERABILITY OF THE OTHER PUMPS IS COMPROMISED. THE FAILURE OF ONE PUMP HAS BEEN PREVIOUSLY ANALYZED. SEE ATTACHED DISCUSSION FOR FURTHER DETAILED INFORMATION.

ATTACHMENT IP-3.20Q-4 Evaluation No. ____

UNREVIEWED SAFETY QUESTION EVALUATION FORM
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2. Does the subject of this evaluation create the possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report? [ ] YES [X] NO

Bases: THE FAILURE OF ONE PUMP HAS BEEN PREVIOUSLY EVALUATED AND IS NOT CHANGED OR OF A DIFFERENT TYPE. SEE ATTACHED DISCUSSION FOR FURTHER DETAILED INFORMATION.

3. Does the subject of this evaluation reduce the margin of safety as defined in the basis for any technical specification? [ ] YES [X] NO

Bases: NO MARGIN OF SAFETY IS CHANGED AS PREVIOUSLY ANALYSIZED. SEE ATTACHED DISCUSSION FOR FURTHER DETAILED INFORMATION.

Note: "Safety analysis report" includes the FSAR, safety analyses submitted to the NRC in support of their review of the application for an operating license and subsequent amendments to the operating license, and other license commitments made to the NRC.

ATTACHMENT IP-3.20Q-4 Evaluation No. ____

UNREVIEWED SAFETY QUESTION EVALUATION FORM
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B. 1. ✓ All of the above questions were answered NO, therefore the originating document does not involve an unreviewed safety question.

2. _____ One or more of the above questions were marked YES, therefore the originating document involves an unreviewed safety question. The originating document, as proposed, shall NOT be implemented without prior approval of the NRC. Provide a recommendation for disposition of the unreviewed safety question below.

RECOMMENDED DISPOSITION: _____

PREPARED BY: Michael F. Hutchison / 5/13/88
ORIGINATOR DATE

REVIEWED BY: [signature] / 5/13/88
COGNIZANT MANAGER DATE

APPROVED BY: Warren H. Kinsey / 5/13/88
PLANT MANAGER DATE

REMARKS: _____

ATTACHMENT IP-3.20Q-4

UNREVIEWED SAFETY QUESTION EVALUATION FORM
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C. If an unreviewed safety question or a Technical Specification change is involved:

____ The NSRB has approved the change.

____ The NRSB has disapproved the change.

_____ / _____
NSRB CHAIRMAN Date

REMARKS: _____

_____

_____

D. If an operating license and/or Technical Specification change is required:

_____ The NRC has approved the proposed change.

_____ The NRC has disapproved the proposed change.

VERIFIED BY: _____ / _____
MANAGER, ENGINEERING AND LICENSING Date

E. If an operating license and/or Technical Specification change is required, verify implementation of the approved change.

VERIFIED BY: _____ / _____
GENERAL MANAGER, NUCLEAR ASSURANCE DATE

USQ 880074
REV 1

FAILURE ANALYSIS OF AUXILIARY FEEDWATER PUMP #14

BACKGROUND

On February 28, 1988, the turbine driven Auxiliary Feedwater pump #14 (D) for Unit 1 failed its performance test; speed was steadily dropping. Speed continued to drop even after adjustments to the governor were performed. No excessive vibration was observed. An inspection of the pump after opening the casing showed that the following parts were damaged: the center shaft bushing next to the 5th stage impeller and the shaft throttle bushing next to the 6th stage impeller. The sleeves for these two locations exhibited the worst damage, including splits in the sleeves located near the keyways. The pump was removed from Unit 1 and was replaced with its Unit 2 counterpart. The damaged pump was shipped back to the Bingham International, the 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) to perform a failure analysis. M&QS completed the failure analysis and sent the results to STP on April 26, 1988. The report indicates that the root cause of the failure was due to stress corrosion cracking in the sleeves. The corrosion progressed until friction forces were generated and resulted in reduction of performance. The material used for the sleeves is common to all the Auxiliary Feedwater pumps; thus the potential for stress corrosion cracking exists in the other Unit 1 pumps.

Through discussions with Bingham, it was decided to change the material used for the sleeves 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 5th, prior to shipment, an inspection was performed and the following damaged noted. One rotating element(pump 23) exhibited a crack, longitudinally, in the center shaft sleeve, which appears to be very similar to the damage of the turbine driven pump. Also, one rotating element exhibited a crack in the wear ring for the 6th stage impeller hub at the rotating pin.

SYSTEM DESCRIPTION

The STP 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 the essential DC power sources. With the exception of the driver sources, all the pumps are identical with relation to configuration and materials used in the pumps.

EVALUATION

The failure analysis performed by the M&OS 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 all design requirements for material type, heat treatment and hardness requirement. The material used for the sleeves is a type 420 stainless steel hardened by heat treatment to 450-525 HB.

Hardened steels, including chromium stainless steels such as Type 420 stainless steel, are subject 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 (i.e. start-up). 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. From all the evidence of the examinations performed it is believed that the cracking in the sleeves is caused by stress corrosion cracking/hydrogen embrittlement and the cracking is intergranular.

It should be noted that stress corrosion cracking/hydrogen embrittlement is time dependent. The stresses on the sleeve is largely residual due to the heat treatment and shrink fit and operating the pump has a negligible effect on the corrosion rate. Also, since the corrosion occurs at a rate dependent upon other varying factors, such as residual stresses in the sleeves, local chemistry, exposure time in the water, and chemical properties of the materials, and 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.

Through discussion with Bingham, the type of sleeve material used at STP is a common material used in their pump manufacturing. They use this material both for nuclear and commercial applications, and indicate that they are not aware of a generic corrosion cracking problem in other operating plants, however one other nuclear plant is presently being investigated for stress corrosion cracking.

FSAR Chapter 15 Analysis requires 2 Auxiliary Feedwater pumps to feed 2 Steam Generators to meet all cooldown conditions for all

LOCA events. Safety analyses are based on the use of 2 Auxiliary Feedwater pumps, and the Technical Specification action statements were developed to maintain those requirements. It should be noted that STP has four auxiliary feedwater pumps and are all covered by the Technical Specifications.

Corrosion pitting is the precursor to the 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 metallurgical 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 it has no effect on pump performance.

The enhanced surveillance testing, discussed below, for the motor-driven pumps provides continued demonstration that the auxiliary feedwater pumps are operating as designed. To date two tests have been performed and evaluated. The results indicate that the pumps are within the expected amperage range and coast down times expected for an acceptable pump. The coast down observations also indicate that the pumps roll to a smooth stop with no abrupt stoppage, abrupt stoppage is a sign of possible degradation. In addition the amperage data has been compared to the original start-up test data and there are no noticeable changes in the readings.

As stated above, water chemistry is a factor for initiation of the corrosion pitting. Unit 1 Auxiliary Feedwater pump #13 had its rotating element changed, with one which was never exposed to water, in May 1987, and thus has always been exposed to the high ph and low oxygen water. Unit 1 Auxiliary Feedwater pump #14(steam driven) was replaced in March 1988 and the rotating element used was the site spare and had never seen any water exposure prior to being installed in Unit 1. Thus, these two pumps have seen only exposure to high ph and low oxygen water and the potential for corrosion pitting has been minimized.

Based on the above discussions and the enhanced surveillance testing, STP considers the Auxiliary Feedwater pumps operable.

ENHANCED SURVEILLANCE TESTING

To provide a higher assurance of operability, the motor-driven pumps shall be operated once a week and the flow rates shall be compared to the surveillance requirements for operability. Also motor current amperage on the pumps shall be monitored for sudden increases in amperage which could indicate pump degradation and the amperage criteria has been provided by engineering. If these

criteria are not met, the affected pump will be declared inoperable and the appropriate Technical Specification action statement will be applied.

The steam driven pump shall be operated once a week and the flow rate shall be compared to the surveillance requirements for operability. If the criteria is not met, the pump will be declared inoperable and the appropriate Technical Specification action statement will be applied. This test will be performed as plant conditions allow(i.e. when steam is available).

If plant conditions exist su that the pumps cannot be operated on a weekly basis, the tests all be performed as soon as plant conditions allow operating the pumps.

In addition to flow requirements, all the pumps(motor and steam driven) shall be observed during the coast down of the pumps. The pumps should coast down to a smooth and uniform stop with no abrupt stoppage observed. The abrupt stoppage may be a sign of pump degradation and therefore needs to be evaluated if seen. The observation is not an operability criteria but is an evaluation of possible degradation.

CORRECTIVE ACTION

Through discussion with Bingham, it has been recommended that the sleeve material on the pumps be changed to a softer stainless steel, such as Type 410 stainless steel hardened to 250-300 HB. This material has been used successfully in earlier models of these type of pumps. This change will eliminate susceptibility to stress corrosion cracking/hydrogen embrittlement as experienced with the harder material presently used, and thereby eliminate this problem.

ATTACHMENTS

Failure Analysis of Shaft Sleeves in an Auxiliary Feedwater Pump