TENNESSEE VALLEY AUTHORITY
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AUG 05 1988

WBRD-50-390/85-25
WBRD-50-391/85-23

10 CFR 50.55(e)

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Gentlemen:

In the Matter of the Application of) Docket Nos. 50-390
Tennessee Valley Authority) 50-391

WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2 - FAILURE IN HIGH PRESSURE FIRE PROTECTION PUMP 2B-B - WBRD-50-390/85-25 AND WBRD-50-391/85-23 - SECOND REVISED FINAL REPORT

The subject deficiency was initially reported to NRC Region II Inspector Al Ignatonis on July 15, 1985, in accordance with 10 CFR 50.55(e) as Nonconforming Condition Report (NCR) W-243-P. This was followed by reports submitted on August 13 and September 12, 1985, and January 29, 1986. Enclosure 1 is our second revised final report as committed in TVA's response to violation 390, 391/87-13-01. Enclosure 2 is a list of new commitments associated with this deficiency.

If there are any questions, please telephone G. R. Ashley at (615) 365-8527.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

R Gridley

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Enclosures
cc: See page 2

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ENCLOSURE 1

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
HIGH PRESSURE FIRE PROTECTION PUMP FAILURE
WBRD-50-390/85-25 AND WBRD-50-391/85-23
NCR W-243-P
10 CFR 50.55(e)

SECOND REVISED FINAL REPORT

Description of Deficiency

In June 1985, high pressure fire protection (HPFP) pump 2B-B failed during operation. During maintenance to replace the upper pump bearing, it was discovered that the packing gland was broken and the pump shaft was loose. Subsequent disassembly and inspection of the pump revealed the following damage: (1) the top line shaft was broken in one location; (2) the bottom line shaft was broken in the thread section; (3) all bearing retainers except for the bottom bearing retainer next to the lower line shaft were broken; (4) all line shaft bearings were destroyed; and (5) the bowl sections had some mud and bearing material inside them.

Initially, sediment was suspected as a leading cause of failure. However, inspection of the HPFP suction pits revealed no significant sediment. During the inspection, it was discovered that the HPFP pump well casings on each pump were 44 inches longer than specified on TVA drawing 37W206-7 R25. Revision 6 of this drawing specified that each well casing be cut and the support removed. However, this change was improperly issued under an S-1 engineering change notice (ECN), and the modification was never implemented. The intent of S-1 ECNs was to make documentation changes only, but EN DES-EP 4.02, "Engineering Change Notices (ECNs) Before Licensing-Handling," governed changes at the time and was unclear regarding the use of type S-1 changes.

While investigating reasons for failure, it was discovered that the axial impeller clearance for all HPFP pumps was set lower than the value specified by the vendor's instruction manual.

On July 9, 1985, pump 2A-A also failed. Disassembly and inspection of the pump revealed that the pump had failed in the same manner as pump 2B-B, with the shaft being broken in essentially the same locations, the bearing retainers broken, and the line shaft bearings destroyed. However, no significant amount of mud was found in the bowl sections of pump 2A-A.

An analysis of the failed line shafts performed at TVA's Singleton Laboratory concludes that the pump shaft fractures all occurred by a fatigue mechanism, with the upper shaft failing after the lower shaft fracture had taken place. Breakage of the bottom line shaft would cause a loss of coolant for the upper line shaft bearings (because these bearings are product-lubricated), induce their failure, and could have subsequently caused the fatigue fracture in the upper shaft. An inspection of the A and B train suction pits found no significant silt in either pit, and mud, although present in the first failed pump, was not found in the second pump that failed. Since the lower shaft failure was a fatigue failure (as opposed to a ductile failure), excess mud and silt have been ruled out as the primary cause of the failure. The analyses also ruled out any defect in the shaft material as the cause.

Additional investigation has not isolated a single root cause of the failures. Possible contributing factors include the following:

1. A previously reported deficiency (WBRD-50-390/86-35, 391/86-32) identified a condition of oversized HPFP discharge relief valves. The vibration and pressure surges induced by the chattering and cycling of the relief valve could have caused abnormal or increased wear of pump and lineshaft bearings and the wear rings. Also, the pumps experienced abnormal loading and movement during this condition which could have initiated a crack that led to the fatigue failure of the shaft.

2. The axial impeller clearances being set below manufacturer's recommendation could cause deflection of the shaft or accelerated wear on the bearings (i.e., the shaft could deflect and wobble if the impellers were dragging or bouncing off the bottom because of improper axial impeller clearance).

3. The HPFP pumps were found to have operated continuously for extended periods of time because of construction activities. Although some wear is expected as the result of normal operation because of the quality of river water, this extended operation may have accelerated the deterioration of the pumps. The two pumps which did not fail in service were examined and found to have excessive wear in the lineshaft bearings, pump bowl bearings, and wear rings. Based on discussions and correspondence with the pump manufacturer, Goulds Pumps Inc., the lineshaft bearing material (Micarta) is considered marginal for the continuous type of service which the HPFP pumps have experienced during the construction phase of the plant. The pumps will not run on a continuous basis during normal power operation of the power plant.

4. The pump wells not being installed according to design could have caused abnormal hydraulic disturbances in the sump, such as vortexing or excitation of the subharmonic resonance. This is the result of the following analyses:

   - Hydraulic modeling of the HPFP sumps (suction pits) by TVA's Norris Laboratory indicates that a wall vortex can occur when the pump well casing extends below the pump bowl. Vibrations from a vortex can cause early bearing wear and possible shaft failure.

   - The results of the vibration analysis performed by Precision Mechanical Analysis (PMA), in order to help establish a preventative maintenance program, identified a potentially destructive subharmonic resonant condition (bearing whirl) occurring at close to fifty percent of running speed. TVA subsequently performed a fatigue analysis for the Micarta bearing material. This analysis showed that shaft bending alone caused by vibrations during normal operating conditions would not be expected to cause shaft failure. On the other hand, subharmonic resonance can be a contributing factor when it occurs in conjunction with, or in the presence of the other contributing factors noted in this report.

Safety Implications

The HPFP pumps are required by Appendix R. In addition to providing fire protection during normal plant conditions, the HPFP pumps supply feedwater to the steam generators during maximum flood conditions. Loss of the pumps during maximum flood conditions or a fire affecting safe shutdown equipment could adversely affect safe operation of the plant.

Corrective Action

All fire pumps were rebuilt with new parts as required. The well extensions were cut to the proper elevation and the seismic supports removed to put the pumps in compliance with the existing design drawings. The impeller clearances were set to the manufacturer's recommended clearance of three-sixteenths of an inch. The pumps were then tested and showed significant improvement in performance. All pumps are now in service.

Note that the oversized relief valves were replaced as part of corrective action for WBRD-50-390/86-35 and 391/86-32.

The manufacturer, Goulds Pump Inc., recommended that the existing Micarta bearings be replaced with fluted rubber bearings in order to correct the subharmonic resonance problem. Goulds submitted a frequency analysis that showed the rubber bearings would shift the natural frequency significantly below the range where problems would occur. The rubber bearings were installed in the 1A-A pump and the pump was subjected to a vibration analysis by TVA.

Based on the preliminary data analysis, it can be concluded that the pump operating characteristics with rubber bearings are an improvement over the Micarta and are acceptable for operation. However, there were some concerns with the dry starts with rubber bearings which could not be evaluated during this testing because a lubricant (Neverseez) had been applied to the rubber bearings during installation. Goulds was sent the preliminary vibration analysis for evaluation. In their response, they stated that calculations from the rubber bearing supplier conclude that the level of heat generated is within safe limits for the rubber supplied.

The Micarta bearings have analytically been proven acceptable using the fatigue life of the shaft at the measured vibration levels. Additional calculations by TVA using rubber bearings have produced similar results. Therefore, selection of the most desirable bearing material shall be based on an evaluation of pump condition at the end of a planned maintenance interval, conducted in accordance with the preventative maintenance program established by TVA. At the end of each maintenance interval, the necessity to install rubber bearings on the remaining pumps will be evaluated.

To prevent recurrence of this condition, the following actions have been taken:

1. To insure that the impeller clearances on these pumps are always set no lower than the manufacturer's minimum recommendation of three-sixteenths of an inch, a note has been added to drawing D2801, "Sectional Model VIT-12X16 BLC-3 Stage," for contract 76K35-83224. The instruction manual

has been updated to include the manufacturer's recommendation. Also, the Watts Bar Nuclear Plant Maintenance Instruction MI-26.22, "High Pressure Fire Protection Pump Disassembly and Reassembly," has been updated.

2. Office of Engineering Procedure OEP-11, "Change Control," was issued on April 26, 1985, to clarify the criteria for exceptions to the ECN process. The current procedure, Nuclear Engineering Procedure NEP 6.1, "Change Control," has superseded OEP-11.

3. The pump manufacturer specifies that as long as the pumped water does not have abrasives, such as sand and silt, at least 500 hours of operating time can be expected for the Micarta bearing. Hour meters have been temporarily installed on all the HPFP pumps, and permanent hour meters will be installed by fuel load of unit 1 to track pump operation for scheduled maintenance intervals.

4. A preventative maintenance program has been established for the HPFP pumps. This program, in conjunction with the previously existing vibration monitoring program data, will ensure the long-term operability of the HPFP pumps. The vibration testing is covered by Surveillance Instruction SI-7.50, "HPFP Pumps," and Technical Instruction TI-31.2, "Plant Equipment Monitoring Program."

ENCLOSURE 2

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
HIGH PRESSURE FIRE PROTECTION PUMP FAILURE
WBRD-50-390/85-25 AND WBRD-50-391/85-23
NCR W-243-P R3
10 CFR 50.55(e)

LIST OF NEW COMMITMENTS

Install permanent hour meters on all high pressure fire pumps by fuel load of unit 1.

ACTION PLAN
390/85-25 and 391/85-23

Action	Responsible Organization	Commitment Due Date
Provide design change for installation of permanent hour meters on all fire pumps	WBEP	03/30/89
Install Permanent hour meters on all fire pumps	Mechanical Maintenance	Fuel load unit 1 (8/15/89)