TENNESSEE VALLEY AUTHORITY

CHATTANOOGA, TENNESSEE 37401
400 Chestnut Street Tower II

November 2, 1984
84 NOV 6 A10 : 27

WBRD-50-390/84-44
WBRD-50-391/84-39

U.S. Nuclear Regulatory Commission
Region II
Attn: Mr. James P. O'Reilly, Regional Administrator
101 Marietta Street, NW, Suite 2900
Atlanta, Georgia 30323

Dear Mr. O'Reilly:

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2 - FAILURE OF AN ERCW SHAFT
WBRD-50-390/84-44 AND WBRD-50-391/84-39 - FINAL REPORT

The subject deficiency was initially reported to NRC-OIE Inspector P. E. Fredrickson on August 29, 1984 in accordance with 10 CFR 50.55(e) as NCR W-195-P. Our first interim report was submitted on October 2, 1984. Enclosed is our final report. We consider 10 CFR Part 21 applicable to this deficiency.

If you have any questions, please get in touch with R. H. Shell at FTS 858-2688.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

L. M. Mills

L. M. Mills, Manager
Nuclear Licensing

Enclosure
cc: Mr. Richard C. DeYoung, Director (Enclosure)
Office of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Records Center (Enclosure)
Institute of Nuclear Power Operations
1100 Circle 75 Parkway, Suite 1500
Atlanta, Georgia 30339

ENCLOSURE

WATTS BAR NUCLEAR PLANT UNITS 1 AND 2
FAILURE OF AN ERCW PUMP SHAFT
NCR W-195-P
WBRD-50-390/84-44 AND WBRD-50-391/84-39
10 CFR 50.55(e)
FINAL REPORT

Description of Deficiency

On August 15, 1984, onsite TVA personnel observed excessive vibrations on ERCW pump unit G-B (S/N 0019). The ERCW pump and motor were then uncoupled and the motor restarted for further testing. Upon starting, the motor shaft appeared to rise "more than usual" and then dropped back down and made contact with the pump adjusting plate and half coupling. The motor was immediately shut off. Subsequent inspection found the adjusting plate jammed against the motor coupling. An attempt to screw the adjusting plate back down the pump shaft was unsuccessful.

On August 17, 1984, the motor was removed to provide access for removing the adjusting plate, which had to be cut off. The threads on the pump top shaft were found to be destroyed. Maintenance Instruction (MI) 67.1 was then initiated to remove and replace the top shaft section. When the coupling at the first shaft joint was removed, the bottom section of the shaft was found to be broken off (see figure 1).

Failure analysis of the fractured shaft indicates that the break was caused by a brittle fracture which most likely occurred under the impact loading induced during the testing of the motor. At the time of the testing, the pump and motor had been uncoupled so that the impeller was resting on its bowl. The energy of the pump-motor impact was transmitted down the pump shaft and dissipated in the coupling threads which caused shaft fracture. The brittle fracture was initiated at a stress corrosion crack (SCC) (which was located approximately 0.030-inches deep and beneath a pit at the shoulder/neck junction of the shaft extension) area of high local stress due to the severe fillet radius of the extension.

The eight ERCW pumps were supplied by Byron-Jackson (B-J) Pump Division of Borg-Warner Corporation under TVA contract number 76K31-83158. B-J pumps of this design are not used elsewhere at Watts Bar or at other TVA nuclear plants. No previous shaft breakage problems had been experienced with the Watts Bar pumps.

Safety Implications

While TVA has determined that an adequate safety margin would exist with flaw depths up to 0.130 inches for a combined normal plus seismic load, there was no mechanism in place before this deficiency to arrest SCC. As such, over the life of the plant, there existed the possibility that the ERCW pump shafts could degrade (as a result of SCC) to the point that operation of the pumps would be impaired. The ERCW is the cooling medium for essential safety-related equipment and a failure of the pump shafts could have adversely affected safe plant operation.

Corrective Actions

TVA has performed extensive metallurgical and structural analysis on the broken shaft. B-J had specified the shaft material to be ASTM A276 type 410 stainless steel. The certified material test report (CMTR) for the broken shaft gave the applicable chemical and mechanical properties. Chemical analyses by TVA were consistent with the CMTR.

Mechanical properties listed on the CMTR, and subsequently confirmed by TVA, are:

Yield Strength	130,500 lb/in^2
Ultimate Strength	147,200 lb/in^2
Hardness	32 RC

This indicates the shaft to be a very strong, relatively hard material.

Charpy V-notch impact test results are as follows:

Temperature ^{o}F	Impact Energy (ft-lb)	Lateral Expansion (MILS)
0	5.0	1.5
30	5.5	2.0
60	9.5	5.0

The Charpy tests show the material to be quite brittle. This characteristic was caused by tempering at $1040^{o}F$.

Failure analysis of the fractured end of the shaft revealed three significant observations--random corrosion pitting, numerous small stress corrosion cracks in the radius of the reduced section at the fracture, and a predominantly integranular fracture. Microscopic inspection of the fracture surface indicated the failure initiation site to be at a small stress corrosion crack located beneath a pit at the shoulder/neck junction of the shaft extension. The small size of the initiating flaw and the predominantly integranular crack propagation indicates a material of low fracture toughness. This is consistent with results of the Charpy test which indicates that failure was by brittle fracture.

Dye penetrant (PT) examination of the other nine shaft sections of the affected pump revealed numerous small pits and cracks in crevice areas of the shafts. Many of the defects were larger than those which initiated failure of the top shaft. Based on the PT examination, the worst shaft was selected for destructive examination in order to characterize the pit depth versus pit width. None of the pits were observed to have stress corrosion cracks except those in the shoulder/neck junction.

During normal operation, all torsional loading is transmitted through the outer coupling and keys. Normal loading on the shaft extension where the break occurred is tensile only and consists of thrust and deadweight. The axial loads are less than 15,000 pounds, producing a tensile stress of about 4800 lb/in^2. Although a stress riser was present at the initiation site it was quite small (0.030 inch), and TVA fracture mechanics analysis indicates a tensile load of 40,000-45,000 pounds (or a comparable bending moment) would be required to cause failure. Even superimposing safe shutdown earthquake

(SSE) loads would not result in nonductile failure for flaws of this size. Flaws as much as four times the depth of those observed would not result in failure under combined normal and SSE loads, although safety margins would be approaching prudent limits.

Therefore, TVA concludes that the shaft failure did not occur in service. This is further substantiated by the fact that high motor amperage was not observed before maintenance as would have been expected had the shaft broken and the impeller dropped onto the bowl and begun rubbing. Also, no unusual wear on the impeller or wear rings was found upon disassembly. Due to this and the unusual movement of the motor shaft, TVA does not consider any programmatic changes of maintenance procedures to be necessary.

However, TVA does plan to modify the pump shaft ends. This modification involves machining down the shaft to eliminate existing pits and turning a radius in lieu of the existing sharp fillet (see Figure 2). This will eliminate the propensity for SCC in the fillet and will reduce the stress concentration to the point that nonductile failure of the shaft end, due to normal plus seismic loading, will not be a concern for the range of flaw sizes that are expected to occur during the design life of plant. The scheduled date of completion for this work on the four pumps needed for unit 1 is January 2, 1985. The remaining pumps will be modified by August 1, 1985.

FIGURE 1

WATTS BAR NUCLEAR PLANT
SCHEMATIC OF BYRON JACKSON ERCW PUMP SHAFT COUPLING

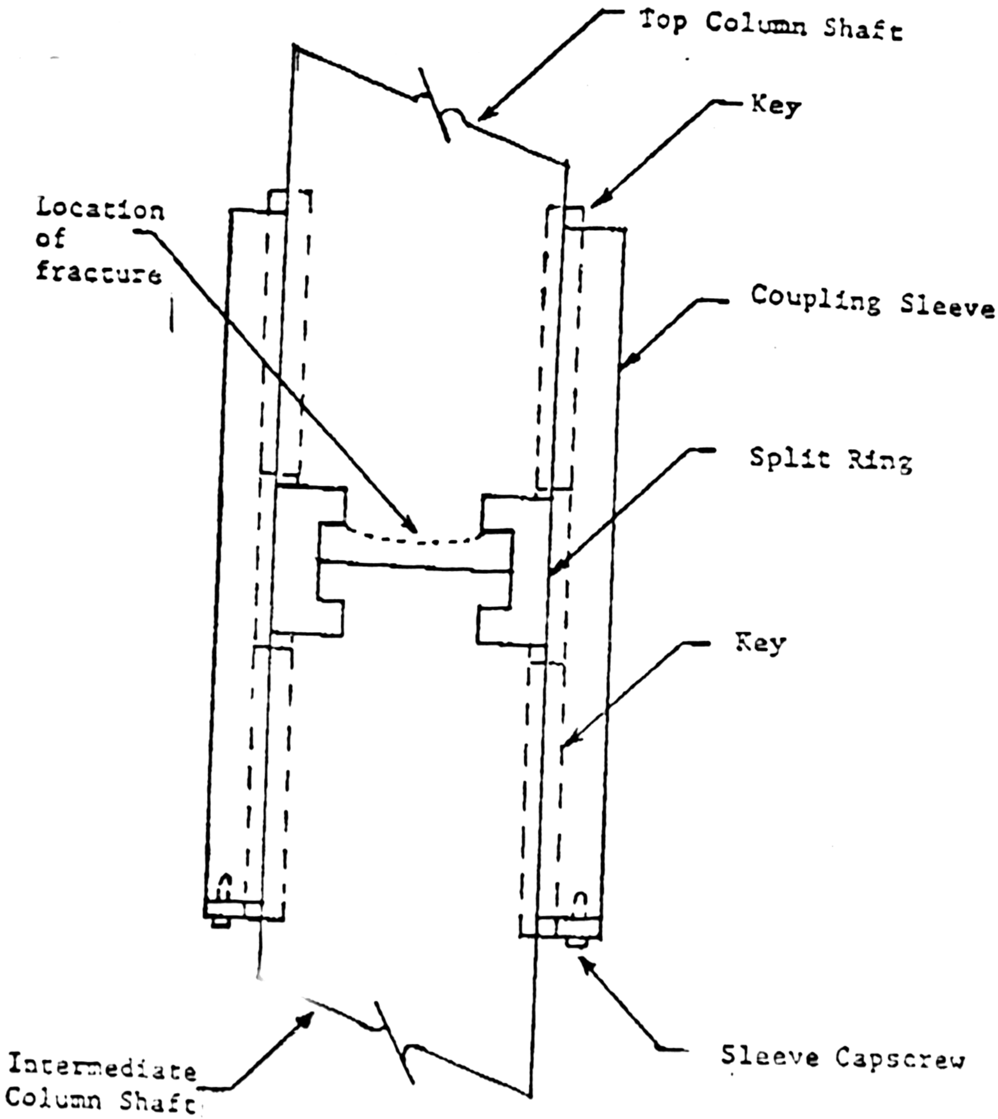

FIGURE 2

WATTS BAR NUCLEAR PLANT
PROPOSED MODIFICATIONS OF THE ERCW PUMP SHAFT ENDS