TENNESSEE VALLEY AUTHORITY
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JAN 31 1991

WBRD-50-390/86-64
WBRD-50-391/87-23

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 Tennessee Valley Authority	))	Docket Nos. 50-390 50-391

WATTS BAR NUCLEAR PLANT (WBN) UNITS 1 AND 2 - FAILED MOTOR PINION KEYS AND MOTOR SHAFT IN LIMITORQUE OPERATOR - WBRD-50-390/86-64 AND WBRD-50-391/87-23 - FIFTH INTERIM REPORT

The purpose of this letter is to provide an interim report for the subject deficiency (Enclosure 1). The interim report describes TVA's progress to date to determine the cause and corrective actions for the failure of the shaft-pinion connection. The deficiency was initially reported to NRC Region II Inspector Morris Branch on October 9, 1986, in accordance with 10 CFR 50.55(e) as Nonconforming Condition Report (NCR) W-477-P for Unit 1. The NCR was subsequently superseded by Condition Adverse to Quality Report (CAQR) WBP 870995; CAQR WBP 870996 was initiated to document the deficiency for Unit 2. Interim reports were submitted on November 12, 1986, March 16 and November 2, 1987, and September 23, 1988. An extension of report schedule was submitted on April 2, 1990.

As discussed in the enclosure, TVA has eliminated several potential reasons for failure of the shaft-pinion connection and is considering corrective action which should prevent unacceptable key/shaft deformations. However, as discussed with NRC's Mr. Ken Barr on December 21, 1990, TVA has been unable to isolate the cause of the subject failures. Therefore, TVA will not be able to submit a 10 CFR 50.55(e) final report for this deficiency until other potential reasons for the subject failure are identified and thoroughly evaluated and until appropriate corrective actions are determined. A final report will be submitted before the system completion date for WBN's Group 2 systems.

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JAN 31 1991

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If there are any questions, please telephone P. L. Pace at (615) 365-1824.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

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ENCLOSURE 1

WATTS BAR NUCLEAR PLANT (WBN) - UNITS 1 AND 2
FAILED MOTOR PINION KEYS AND MOTOR SHAFT IN LIMITORQUE OPERATOR
WBRD-50-390/86-64 AND WBRD-50-391/87-23
CAQRs WBP 870995 AND WBP 870996
10 CFR 50.55(e) FIFTH INTERIM REPORT

Description of Deficiency

During preventive maintenance for the actuator on valve 1-FCV-63-72A (the isolation valve for residual heat removal [RHR] pump suction from containment sump), the motor shaft-pinion gear key connection was found damaged. The key was found deformed and located approximately one-third out of its slot. The motor shaft was found cracked in two places. The redundant train valve actuator (1-FCV-63-73B) was then examined, which revealed a similarly deformed key, still in complete engagement with no motor shaft cracking. The failed actuators are model SB-3, manufactured by Limitorque Corporation, Lynchburg, Virginia, equipped with 100 foot-pound force motors. These actuators were provided to TVA by Westinghouse Electric Corporation, Pittsburgh, Pennsylvania, under the Nuclear Steam Supply System (NSSS) contract 71C62-54114-1. As discussed in previous reports on this issue, TVA has identified other examples of key/shaft deformation and/or cracking in various actuators. Attachment 1 summarizes technical information and the nature of damage for the actuators inspected to date.

Although several types and sizes of actuators have demonstrated key/keyway deformation and/or cracking, TVA has preliminarily bounded the problem to 30 high speed, size 2, 3, and 4 actuators on safety-related valves installed in Unit 1 and Unit 2 (see Table 1 below). This preliminary bounding was possible based on testing and analysis by Limitorque Corporation which resulted in establishing a deformation acceptance criteria of 8 mils for the motor shaft keyway. This is discussed further in this report.

TABLE 1 - Safety-related valves with size 2, 3, or 4 Limitorque actuators having stem speeds exceeding 50 inches per minute

1,2-FCV-3-33-A	1,2-FCV-63-67-B	1,2-FCV-63-94-B
1,2-FCV-3-47-B	1,2-FCV-63-72-A	1,2-FCV-63-98-B
1,2-FCV-3-87-A	1,2-FCV-63-73-B	1,2-FCV-63-118-A
1,2-FCV-3-100-B	1,2-FCV-63-80-A	1,2-FCV-74-3-A
1,2-FCV-63-1-A	1,2-FCV-63-93-A	1,2-FCV-74-21-B

Cause Evaluation

The exact failure mechanism and root cause of the key/shaft deformation and cracking problems are not known. However, TVA believes that a change in shaft material and shaft design may prevent the problem. As discussed below, several failure mechanisms including hammer blow impact loading, material strength, material defects, and operational anomalies were eliminated as individual root causes. Several of these potential causes were explored during extensive testing at Limitorque and at the WBN facility.

First, as noted in previous reports, impact loading due to the hammer-blow design was eliminated as a cause when similar key/shaft deformations resulted for an actuator tested under both hammer-blow and non-hammer-blow configurations.

Second, increasing the strength of the keys/shafts has not reduced the deformation to an acceptable limit. A motor shaft and key, both made of type 4140 carbon steel (harder and more resistant to cracking than the original 1144 material), were installed in 1-FCV-63-72A. The valve was cycled 15 times while performing a MOVATS (Motor-Operated Valve Analysis and Test System) diagnostic test and resulted in keyway deformation of approximately 0.020 inches and slight key indentations along both sides. Though cracking was not apparent under the limited cycling encountered, the deformation criteria eliminated the use of higher strength material in the motor shaft and key as a sole acceptable corrective action.

Although strengthening shaft material from AISI 1144 to AISI 4140 does not appear to prevent unacceptable keyway deformation, the use of 4140 should eliminate the type of crack propagation occurring in type 1144 material once excessive keyway widening occurs. Inspection of the AISI type 1144 motor shafts for 1-FCV-63-72A and 2-FCV-63-72 found cracking initiating at the keyway corner and propagating circumferentially. This type of cracking is indicative of rapid impact overloading which initiates a cleavage followed by ductile tearing. The microstructure of the tested shafts showed numerous manganese sulfide stringers which provided a path for crack propagation. This type of material is generally considered inappropriate for applications of dynamic loading because the nonmetallic inclusions may act as stress risers that provide initiation sites and propagation paths for mechanically induced cracking. Motors typically would not be a source of dynamic loading as they are built for continuous duty. Motors for valve actuators, however, operate for very short durations and reverse cycle. The motor shaft keys exhibited tensile overloading failures which would have followed any cyclical loading after keyway deformation.

Third, TVA's metallurgical report on the shaft and key failures for 1-FCV-63-72A and 1-FCV-63-73B indicated that the metallurgical properties of two keys and a failed shaft were within the limits of the material specification (AISI type 1018 carbon steel for the keys and AISI type 1144 for the shaft) and that no metallurigical defects were involved in the failures.

Fourth, based on valve history and worst-case calculations by Limitorque, TVA does not consider abnormal operating conditions to be a cause or a contributing factor for the failure. TVA wiring configurations do not allow instantaneous motor reversal. Powered motor operation must be stopped before reversing the motor. Additionally, valve history for valves 1-FCV-63-72A and 1-FCV-63-73B, indicates no recorded occurrences of torque or limit switch failures or of excessive unseating forces.

To determine whether other utilities may have experience or information relating to this deficiency, WBN placed an item in the Nuclear Network in March 1989. Of six responses received to date for this item, none have indicated encountering problems with motor shaft key/keyway deformation and/or cracking.

Extent of Deficiency

As a result of finding this problem on three different size actuators, TVA inspected additional actuators. The results of these inspections are included in Attachment 1. As stated previously, Limitorque has established a keyway deformation acceptance criteria of 8 mils. Based on this deformation criteria and comparisons of different size actuators (described below), TVA has preliminarily bounded the problem to high-speed, size 2, 3, and 4 actuators. The full extent of the deficiency will be determined during additional research into the cause of the motor shaft/key deformations.

As Attachment 1 illustrates, TVA's inspection found keyway deformation exceeding the 8 mil criteria for several size 2, 3, and 4 actuators which produce stem speeds greater than 50 inches per minute. The inspection found keyway deformation of less than 8 mils for five inspected size 2, 3, and 4 actuators producing stem speeds of approximately 12 inches per minute and less. TVA determined the only WBN valves with a stem speed of more than 50 inches per minute have size 0, 2, 3, and 4 actuators (Refer to Table 2). All size 1 actuators have a stem speed of approximately 12 inches per minute or less and can be expected to pass the deformation criteria as their torque rating is lower than the larger size 2, 3, and 4 slow speed actuators which had acceptable deformations. Likewise, all size 0, 00, and 000 actuators can be expected to pass the deformation criteria based on inspection results for 1-FCV-72-39-A. This size 0, high torque actuator has a speed greater than 50 inches per minute and showed keyway deformation of less than 8 mils. As impact loading decreases with decreasing speeds and torque applied, slower size 0 actuators and the smaller size 00 and 000 actuators should pass the deformation criteria. Therefore, it appears only high speed size 2, 3, or 4 actuators will require corrective action. However, as discussed above, the full extent of the deficiency will be further explored.

Note: WBN has no size 2, 3, or 4 actuators with stem speeds between 12 and 50 inches per minute.

TABLE 2 - Tabulation of valve stem speeds

ACTUATOR	SPEED IN INCHES PER MINUTE					
SIZE	<12	<20	<30	<40	<50	>50
000	X			X	X	
00	X	X	X	X	X	
0	X				X	X
1	X					
2	X					X
3	X					X
4	X					X

Safety Implications

The damage to 1-FCV-63-72A and 1-FCV-63-73B had been identified as a result of preventative maintenance being performed on their actuators. The actuators were considered to be in an operational status prior to this maintenance. The keyway deformation, while outside the Limitorque acceptance criteria, would not cause an immediate concern. Complete or partial circumferential cracking of the motor shaft would not be considered detrimental since (1) torque is transmitted by the outer portion of the shaft, (2) radial expansion of the shaft (flaring out of the keyway) would be constrained by the motor pinion attached to it, and (3) the key is sufficiently sized to transmit the required loads through the rest of the power train. Only where shaft cracking leads to key shearing or disengagement would the actuator be rendered inoperable.

As a result of finding a sheared key in the actuator for 1-FCV-63-94-B, TVA's position is that shaft cracking and excessive keyway deformation (i.e., exceeding Limitorque's 8 mil criteria) would eventually render the valves inoperable. Failure of valves 1-FCV-63-72A and 1-FCV-63-73B to operate could result in loss of the ability to recirculate water from containment following a loss of coolant accident (LOCA). Therefore, this deficiency could have adversely affected the safety of operations of the plant.

Corrective Action

In discussions with Limitorque Corporation and with their concurrence, TVA has suggested splining the motor shaft to the motor pinion using the higher strength 4140 shaft material for those actuators showing rapid impact overloading. The splined shaft would provide more contact points to take the torque thus distributing the effects of the rapid impact loading. The use of the high strength material would eliminate the sulfide stringers as a source of crack propagation. Implementation of this approach without having established the cause of the failures would be subject to follow-up inspections to verify the actuator components had not been adversely affected as a result of splining the shafts. This approach is under consideration.

ENCLOSURE 2

LIST OF COMMITMENTS

TVA will submit a final report for the subject deficiency before WBN's scheduled system completion date for Group 2B systems.

ATTACHMENT 1

INSPECTION RESULTS

VALVE	SIZE	MATERIAL KEY/SHAFT	TORQUE (FT-LBS)	SPEED (IN/MIN)	KEY/KEYWAY CONDITION
1-FCV-72-39-A	SBO	See note	25	51.5	Key scored, no keyway damage
1-FCV-63-94-B	SBD2	See note	80	57.8	Key sheared, shaft cracked
1-FCV-74-3-A	SB2	See note	80	64.8	16 mil keyway deformation
1-FCV-3-205	SMB3	4140/1144	150	12.0	No damage
1-FCV-2-221	SMB3	1018/1144	100	12.3	Slight key indenting, 4-8 mil keyway widening
1-FCV-2-224	SMB3	1018/4140	100	12.3	Slight key indenting, 4-8 mil keyway widening
1-FCV-63-72-A	SB3	1018/1144	100	55.0	Cracked shaft, keyway widened, key deformed
1-FCV-63-73-B	SB3	1018/1144	100	55.0	Key deformed, keyway widened
2-FCV-63-72-A	SB3	1018/1144	100	55.0	Shaft cracked, key deformed, keyway widened
2-FCV-63-73-B	SB3	1018/1144	100	55.0	Key deformed, keyway widened
1-FCV-63-67-B	SBD3	4140/1144	150	62.9	Key scored, 25-30 mil keyway deformation
1-FCV-63-80-A	SBD3	4140/1144	150	62.0	Key scored, 25-30 mil keyway deformation
1-FCV-63-98-B	SBD3	4140/1144	150	62.9	Key scored, 25-30 mil keyway deformation
1-FCV-63-118-A	SBD3	4140/1144	150	62.9	Key scored, 25-30 mil keyway deformation
1-FCV-3-67	SMB4	4140/1144	150	12.1	No damage
1-FCV-3-81	SMB4	4140/1144	150	12.1	No damage
1-FCV-3-100-B	SB4	4140/1144	300	180.9	15-20 mil keyway deformation, no key damage

Note - Material information unavailable