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DESCRIPTION

ENCLOSURE

Consists of the B&W Metallurgical Evaluation and Failure Analysis Report on the Crystal River Unit 3 failed shaft.....

(3-P)

(1/4")

PLANT NAME: Three Mile Island Unit No. 1

* Photos will be sent to Reg. File then L.A.: [redacted]

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September 28, 1977
GQL 1317

Director of Nuclear Reactor Regulation
Attn: R. W. Reid, Chief
Operating Reactors Branch No. 4
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

Three Mile Island Nuclear Station Unit 1 (TMI-1)
Docket No. 50-289
Operating License No. DPR-50
Decay Heat Pump Shafts

In accordance with our September 8, 1977 commitment please find attached the B&W Metallurgical Evaluation and Failure Analysis Report on the Crystal River Unit 3 failed shaft. In summary, the report indicates that:

1. The crack initiated along a bottom corner of the keyway. Crack initiation appears to have been due to fatigue.

2. The direction and type (shear mode) of initial crack growth is consistent with stresses from torsional loading.

3. The crack morphology is not consistent with crack initiation or growth by impact overload or stress corrosion cracking.

4. The shaft does not appear have received a proper H1150 heat treatment, but rather appears to have received a heat treatment somewhat like an H1025 heat treatment.

5. The questionable heat treatment and the non-filleted keyway are the metallurgical factors that led to the failure of the Crystal River III Decay Heat Pump Shaft.

Met-Ed, GPUSC, and MPR have evaluated the B&W Metallurgical Report; pump performance data accumulated by both Worthington and Met-Ed; the results of the pump design review being performed by MPR, B&W and Met-Ed; Armco material data correlating fatigue properties of 17-4 PH with 4140 alloy steel; and the material documentation verification that was performed.

Key points of the evaluation are outlined below:

1. Worthington assured Met-Ed in a meeting on September 20, 1977 that thousands of this type of pump have operated satisfactorily with no reported cases of shaft failures. Worthington stated that all of these pump shafts have had the sharp cornered keyways similar to those believed to be in the TMI-1 pump shafts. These were fabricated from 4140 alloy steel. Worthington has advised us that 161 pumps are in service that are the same size as the CR-3 and TMI-1 decay heat pumps. This broad base of experience gives us confidence based on operating history that the TMI-1 Decay Heat Pump design is of proven reliability with a large margin of safety.

2. The shaft material of the CR-3 and TMI-1 pumps is 17-4 PH specified in the H1150 heat treated condition. The B&W Metallurgical Evaluation and Failure Analysis indicates that the CR-3 failed shaft properties were somewhat similar to the H1025 heat treated condition. Armco fatigue strength data shows that 17-4 PH material in the H1025 heat treated condition has a higher longitudinal and transverse, smooth or notched, fatigue strength than the 4140 alloy steel used by Worthington for their standard commercial pumps of the same design. We expect that all H1150 fatigue properties would improve over those of the H1025 heat treated material documented for smooth bar longitudinal specimens.

   Due to the fact that 17-4 PH material in both the H1025 and H1150 heat treated conditions is superior in fatigue properties to the 4140 alloy steel used by Worthington for their standard commercial pump of the same design, we have concluded that the excellent operating experience with the 4140 alloy steel shaft is applicable to the TMI-1 Decay Heat Pump Shafts.

3. The TMI-1 pump shafts were fabricated from a different heat of material about a year before the CR-3 shafts. We have confidence that the TMI-1 shafts were heat treated correctly.

4. Load and stress analyses performed by MPR and Worthington indicate that applied cyclic stresses on the shaft are considerably less than would be expected to cause fatigue failure. While there is some uncertainty as to the loads that are experienced under low flow conditions, the credible upper bound stresses are well below the fatigue endurance limit, for 17-4 PH material heat treated to H1025 or higher.

5. The TMI-1 pumps have already operated satisfactorily about 3 to 4 times that length of time which caused failure of the CR-3 pump. Ultrasonic inspections have confirmed that there are no transverse defects greater than 24 mils deep in the TMI-1 shafts. The vibration tests of the TMI-1 pumps show that they are quiet, smooth running pumps with very low levels of vibration. Based on these vibration and UT inspections we concluded that these pumps are not subjected to high loads.

B&W has recommended decay heat pump shaft replacement at TMI-1, because the TMI-1 Decay Heat Pump Shafts probably have sharp corner keyways; documentation is not available to substantiate the TMI pump shaft heat treatment[1]; and B&W's metallurgical analysis concludes that the CR-3 failure was due to improper shaft heat treatment interaction in combination with the sharp corner keyway.

[1] Records prior to 1971 were destroyed in accordance with the previous Worthington practice of 5 year record retention.

In view of B&W's shaft replacement recommendation, Met-Ed is currently investigating the feasibility of metallographic replication and hardness tests to verify the heat treated condition of the TMI shafts. We are also considering the advisability of shaft replacement during the spring 1978 refueling.

It is Met-Ed's present intent to accomplish the above tests and analyze the data within the next 6 weeks.

Sincerely,

J. G. Herbein
Vice President

JGH:WEP:tas

Attachment: B&W Metallurgical Evaluation
and Failure Analysis Report