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10 CFR 2.201

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Browns Ferry Nuclear Plant, Units 1, 2, and 3
Facility Operating License Nos. DPR-33, DPR-52, and DPR-68
NRC Docket Nos. 50-259, 50-260, and 50-296

Subject: **Information Related to the Safety Significance of the Apparent Violation Concerning Failure of Unit 1 Residual Heat Removal System Low Pressure Injection Valve**

Reference: Letter from NRC to TVA, "Browns Ferry Nuclear Plant - NRC Integrated Inspection Report 05000259/2010005, 05000260/2010005, 05000296/2010005, and Notice of Violation," dated February 9, 2011

The referenced Inspection Report documented a self-revealing apparent violation concerning the failure of a Unit 1 Residual Heat Removal (RHR) system low pressure injection valve 1-FCV-74-66. Specifically, the valve disc separated from the valve stem and disc skirt, and was found seated and stuck in the valve seat. This prevented RHR Loop II flow when operators attempted to place that loop into service for shutdown cooling on October 23, 2010 during the last refueling outage. The finding was characterized as having a potential safety significance greater than very low safety significance (Green), because it adversely affected the operators' ability to achieve safe shutdown. Specifically, the valve was assumed to be inoperable since the last time that flow was confirmed to have passed through it, i.e., March 13, 2009, and the date when operator attempted to put RHR Loop II in service, October 23, 2010. The safety characterization was noted in the report as To Be Determined (TBD).

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Based on the expectation noted in Section 08.03 of NRC Inspection Manual Chapter 0609 "Significance Determination Process," the Tennessee Valley Authority (TVA) is providing information considered applicable to finding. This technical information summarizes laboratory testing and analysis contracted by TVA. TVA concludes that flow vibrations induced by the running RHR pump would have unseated the disc for valve 1-FCV-74-66 within a short period of time; thus, the associated RHR loop would have been able to fulfill its safety function during the period of apparent inoperability.

The summary of the laboratory testing and analysis results is contained in the enclosure.

There are no new regulatory commitments in this letter. Should you have any questions concerning this submittal, please contact Tom Matthews at (423) 751-2687.

Respectfully,

R. M. Krich

Enclosure:
Evaluation of Browns Ferry Nuclear Plant, Unit 1, Injection Valve Failure

cc (Enclosure):
NRC Regional Administrator - Region II
NRC Senior Resident Inspector - Browns Ferry Nuclear Plant

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Evaluation of Browns Ferry Nuclear Plant, Unit 1, Injection Valve Failure

1. Laboratory testing and analysis was performed by Performance Improvement International.
2. Valve disc separation mechanism.
    a. The skirt thread diameter was undersized (38% of original strength).
    b. Tack welds and the threaded connection failed over time.
    c. The stem and skirt pulled away from the disc.
    d. Multiple valve stroke surveillances pushed the disc further into the valve seat; the disc could have experienced up to 13 cyclic impacts by the valve stem after separation and when operators attempted to put the Residual Heat Removal (RHR) system in service on October 23, 2010.
    e. A material analysis determined the separation mechanism to be multiple overload pull-outs, but the time of failure was indeterminate.
3. Analysis of force balance and coefficient of friction significance.
    a. A two-dimensional static analysis was performed to determine the normal force and coefficient of friction.
    b. The calculated coefficient of friction was well aligned with the method discussed in the Idaho National Laboratory stellite aging research.[1]
    c. An energy balance approach was used to determine the energy applied by the disc to the valve body and associated deflection from each stem stroke.
    d. Finite Element Analysis results showed the following.
        i. There was a close correlation with the simplified Roark stiffness used in the work energy approach.
        ii. Slight plastic deformation limited the axial deflection, suggesting the simplified linear elastic approach produces a conservative frictional force.
4. Vibration effect on the coefficient of friction.
    a. A very similar experiment conducted by researchers concludes that vibrations greatly reduce the coefficient of friction.
    b. The coefficient of friction is most reduced by vibration frequency and amplitude, surface roughness, speed, and quadratic terms of the surface roughness and speed.
    c. For RHR valve 1-FCV-74-66 as installed, the pump vanes for RHR pump 1B induce vibration (pressure pulses transmitted through water) during system operation.
    d. Laboratory testing
        i. A model valve disc was compressed into a model valve body by a hydraulic press.
        ii. Strain gauges were positioned on the outside of the valve body.
        iii. Two separate tests were performed using vibration and simulated system pressure applied to the model.

iv. The vibration was limited to lower frequency and amplitude that were observed during RHR pump 1B field testing at Browns Ferry, Unit 1.
v. Both laboratory tests showed a significant effect on the coefficient of friction as published research has indicated.
vi. The time needed for the vibration to release the disc from the seat ranged from 2 to 7 minutes.

5. Conclusion.
   a. Forensics, laboratory testing, and analysis indicate the stuck valve disc would be released from the seat within 7 minutes of starting RHR pump 1B. Adequate flow would thus be provided within the required time frame for the system to perform its safety function.
   b. The conclusion is based upon sound research and supported by testing and analysis.
   c. Further tests are planned to fully bound the variations in coefficients of friction.

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[1] INEEL/EXT-02-01-021, "Results of NRC-Sponsored Stellite 6 Aging and Friction Testing," October 2002.