September 26, 2008

MEMORANDUM TO: Donald G. Harrison, Acting Chief
Safety Issues Resolution Branch
Division of Safety Systems
Office of Nuclear Reactor Regulation

FROM: John Lehning, Reactor Systems Engineer
Safety Issues Resolution Branch **/RA/**
Division of Safety Systems
Office of Nuclear Reactor Regulation

SUBJECT: NON-PROPRIETARY VERSION: STAFF OBSERVATIONS OF FORT CALHOUN STATION STRAINER TESTING FOR GENERIC SAFETY ISSUE 191 DURING FEBRUARY 18–19, 2008, TRIP TO CONTINUUM DYNAMICS, INCORPORATED

On February 18–19, 2008, the Nuclear Regulatory Commission (NRC) staff traveled to the Continuum Dynamics, Incorporated (CDI), strainer testing facilities in Ewing, New Jersey, to observe containment sump strainer testing performed by General Electric (GE) for Fort Calhoun Station. The testing observed by the staff was intended to support the resolution of strainer performance issues associated with Generic Safety Issue 191 (GSI-191). The participating NRC staff member was John Lehning of NRR/DSS/SSIB.

The staff observed a test case for Fort Calhoun that was intended to represent a small-break loss-of-coolant accident located in the vicinity of the sump strainers. The testing for Fort Calhoun resulted in a head loss that was within the allowable margin. Nevertheless, the testing demonstrated again the potential for a considerable measured head loss to result from debris loadings with significantly less than a theoretical 1/8-inch debris layer. Overall, the staff concluded that the Fort Calhoun test case observed during the trip was conducted in a reasonable manner and noted that the procedure used for the observed test case addressed a number of NRC staff concerns with previous GE/CDI test procedures that were identified in the staff's GSI-191 audit of Waterford 3 Steam Electric Station.

In addition to the test observed for Fort Calhoun, the staff observed parts of a chemical effects head loss test for Seabrook Station that was being conducted in a different test rig, including the addition of chemical precipitates to the test tank.

The enclosed trip report provides a detailed description of the staff's head loss testing observations during the trip to CDI.

Enclosure:
As Stated

CONTACT: John Lehning, NRR/DSS/SSIB
301-415-1015

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Non-Proprietary Trip Report
Observation of Fort Calhoun Strainer Testing at Continuum Dynamics

Introduction

On February 18–19, 2008, the NRC staff traveled to Ewing, NJ, to observe strainer testing for Fort Calhoun Station. The testing was conducted by General Electric (GE) and Continuum Dynamics, Incorporated (CDI), at the CDI test facilities. The head loss test observed by the staff was intended to model a small-break loss-of-coolant accident (LOCA) located in the vicinity of the sump strainers. The staff estimated that the quantity of fibrous debris added to the test tank was sufficient to create a uniform debris bed with a theoretical thickness of approximately 1/20th of an inch over the strainer. The measured head loss at the termination of the test was approximately 2.6 ft, although as explained subsequently, this value was still slowly increasing at the termination of the test. The measured head loss was within the allowable head loss margin for Fort Calhoun. The staff noted that the procedure used for the Fort Calhoun test observed by the staff addressed a number of staff comments on previous GE/CDI head loss test procedures used for other plants' testing.

Although the primary focus of the staff's trip was to observe the testing conducted for Fort Calhoun, the staff also observed portions of a chemical effects head loss test for Seabrook Station that was being conducted in a different test rig, including the addition of chemical precipitates to the test tank.

This trip report has been reviewed by Fort Calhoun and its test vendors for proprietary information. All proprietary information identified by the review has been redacted from this report.

Fort Calhoun Head Loss Test Program

The test case observed by the NRC staff was one in a series of head loss tests performed by GE/CDI for Fort Calhoun. The Fort Calhoun head loss test program included various large-break LOCA test conditions, as well as two small-break LOCA conditions.

Based upon the results of testing completed prior to the staff's trip to the CDI facilities, it was determined that the most limiting test condition for Fort Calhoun was a small-break LOCA located near the sump strainers. The debris quantities for the large-break LOCA test conditions typically were larger than those for the small-break cases. However, the staff understood that, for the large-break LOCA conditions, the pipe rupture was not located in the vicinity of the sump strainers, and agitation of the test tank along the approach to the strainer was not performed. As a result, vendor personnel indicated that the quantity of debris that settled under large-break LOCA test conditions was significantly greater than the quantity that settled under small-break LOCA conditions. The NRC staff did not observe large-break LOCA testing, and, thus, evaluation of the prototypicality of the near-field settling under large-break LOCA test conditions was not within the scope of the staff's trip.

In addition to the different test conditions considered above, the Fort Calhoun test program included several repetitions of the small-break LOCA case that achieved the most limiting head loss. Based on discussions with test vendor personnel, the staff understood that the approximate head losses measured for the repeated test condition showed significant variation:

0.5 inch, 2.6 ft, 3.75 ft, and 5.9 ft. Had only one test been performed, it is unclear whether a conservative head loss value would have resulted. The staff considers it essential that licensees have confidence that head loss test results are repeatable or bounding. Repeating tests with the same conditions and using the most limiting value in the strainer performance analysis provides confidence that a conservative head loss value has been used for the strainer design. The staff noted that the good practice of performing repeat head loss tests had also been observed during a previous trip to witness GE/CDI testing for a different licensee.

Test Setup

The Fort Calhoun test was conducted in a test tank that was essentially an above-ground swimming pool that had been modified for conducting hydraulic testing. The test strainer was a 15-disk stacked-disk module that was located near one of the plywood baffle walls set up inside the test tank to limit the size of the actively recirculating region of the tank. Adjacent to the test module was a box that was intended to model a basket containing sodium tetraborate that is adjacent to plant strainer modules.

A number of agitators and the return header induced significant turbulence into the test tank volume. The agitators and return header were not located in the direct vicinity of the test module.

Test Debris

The debris added to the observed head loss test is listed in Table 1, below. Note that a comparison of the characteristics of the test debris to characteristics of expected post-LOCA debris at Fort Calhoun was beyond the scope of the staff's head loss testing observations.

Table 1: Debris Added to the Observed Fort Calhoun Head Loss Test

Debris Type	Debris Form
Nukon® low-density fiberglass	Fine fibers
Silicon carbide	Fine particulate (average diameter of 10 μm)
Calcium silicate	Fine particulate (sifted through 1/10-inch screen)
Paint chips	Chips (sifted through 1/8-inch screen)
Sodium aluminum silicate precipitate	WCAP-16530 recipe
Aluminum oxyhydroxide precipitate	WCAP-16530 recipe

Based upon a rough calculation using approximate values provided by vendor personnel, the staff estimated that the quantity of fibrous debris for the observed test would create a uniform layer with a theoretical thickness of approximately 1/20th of an inch. The particulate-to-fiber mass ratio for the observed test was approximately 20.

Test Observations

With recirculation flow established through the test module and the agitators activated, the test technicians began the sequence of debris addition for the test. From start to finish, the staff estimated that the test ran for roughly 30 hours.

Based on the predictions of the Fort Calhoun debris transport calculation, the vendor stated that all of the fibrous debris added to the head loss tank should be in the form of fines. Each batch of dry fibrous debris had been weighed and was contained in a plastic drink cup when the staff arrived at the test site. Vendor personnel stated that the fibrous debris used for the Fort Calhoun test had been passed through a leaf shredder five times. Vendor personnel stated that this process for fragmenting fibrous debris had recently been implemented in an attempt to address NRC staff concerns with fibrous debris preparation during GE/CDI testing identified during the audit of Waterford 3 Steam Electric Station.

The staff noted that one potential improvement to the vendor's procedure for mixing up fibrous debris would be to provide objective standards for debris slurry concentrations and/or mixing times to ensure consistency in the properties of prepared debris. While no concerns with debris preparation were identified during the Fort Calhoun testing, the staff recommended that, for future licensees' testing, the GE/CDI procedures should check the adequacy of a debris slurry using the same mixing concentration and preparation technique as would be used for the debris slurry actually added to the test tank.

The staff observed that test technicians poured the buckets containing the debris slurries into the test tank fairly rapidly. Rapid pouring of debris into a test tank has the potential to create downward currents in the test tank that could cause suspended debris to approach and settle onto the tank floor. In the test observed by the staff, strong agitation induced by stirrers in the area where debris was added to the test tank prevented this practice from resulting in non-prototypical debris settlement. However, the staff recommended that, for head loss tests with little or no agitation, the addition of debris should be performed more slowly to ensure prototypicality.

The GE/CDI test plan specified properties for the paint chips used for the observed test. The staff had questions about some of the specified properties, but verifying the prototypicality of test debris to actual plant debris was beyond the scope of the staff's head loss testing observations.

The staff had questions on the proprietary methodology used by GE for the addition of chemical precipitates in the Fort Calhoun testing and requested that the vendor provide the technical basis for the addition sequence. Based upon proprietary discussions with the vendor, the staff did not consider the GE chemical precipitate addition sequence to be a concern for the Fort Calhoun testing. However, the staff indicated that the proprietary methodology may not be acceptable for application to other specific debris loading and test conditions.

As expected given the small quantity of fibrous debris for the observed test, the measured head loss did not significantly increase until the majority of the fiber had been added. The fibrous debris additions that resulted in a measurable head loss response occurred during the night shift and were not observed by the staff. The final batch of chemicals was added the next morning, which resulted in a steep head loss increase followed by a slow and steadily increasing trend that persisted over approximately five hours until the test was terminated. A

detailed review of the licensee's test termination criteria was beyond the scope of the staff's head loss testing observations.

Post-Test Observations

At the conclusion of the head loss test, vendor personnel continued to run the test pump while gradually draining water from the test tank. The submergence height at which air audibly began to be sucked through the strainer was measured and recorded. No vortexing or air ingestion concerns were identified with the strainer submerged at a test tank water level representing the minimum containment water level for Fort Calhoun.

Based upon observations made during a previous trip to observe testing at GE/CDI, the staff evaluated whether the effect of agitation in the test tank appeared to inhibit the formation of a uniform layer of debris over the test strainer. The GE/CDI test procedure originally incorporated agitation for some tests in response to NRC staff comments concerning debris settlement in the test tank. Although the staff considered this method effective at preventing settling during a later trip to observe another GE/CDI test, the staff observed that the agitation in the test tank was so strong that the formation of a uniform debris layer over the outermost surfaces of the test module may have been inhibited. Following the draindown of the test tank for the observed Fort Calhoun test, the staff visually observed that (1) minimal debris had settled in the test tank and (2) a relatively uniform layer of debris had formed over all surfaces of the test strainer. Therefore, the staff considered the level of agitation used by GE/CDI for the observed Fort Calhoun test to be appropriate.

A detailed review of the licensee's viscosity correction methodology was beyond the scope of the staff's head loss testing observations. However, the staff noted that NRC-approved methods for performing viscosity correction in the presence of boreholes and other differential-pressure-driven bed degradation mechanisms do not currently exist.

The staff and vendor discussed the extrapolation of measured head loss results. The staff noted that the NRC's strainer head loss and vortexing review guidance (ML080230038) states that it is appropriate to extrapolate measured head loss results by scaling the test time to the sump mission time, because some phenomena which affect filtration efficiency, such as degradation or compaction of a debris bed, can be caused by time-dependent processes. A detailed review of the licensee's extrapolation methodology was beyond the scope of the staff's head loss testing observations. Such a review might have revealed mitigating factors that could allow the staff to accept the licensee's extrapolation approach as applied to Fort Calhoun.

Test Observations for Seabrook Station

The testing for Seabrook Station was performed in a tall, thin tank with an upper section, where debris was added, and a lower section, where the test strainer module was located. Heavy agitation was maintained in the upper region to prevent debris settling. The staff did not make extensive observations of the Seabrook testing, since observing the Fort Calhoun testing was the purpose of the staff's trip. The staff's limited observations from the Seabrook testing are provided below.

As discussed above, following NRC staff comments during the audit of Waterford 3, the previous GE/CDI procedure for the fragmentation of fine fibrous debris had been improved for the Fort Calhoun testing to require five passes through a leaf shredder. However, for the Seabrook testing, vendor personnel indicated that only two passes through a leaf shredder had

been performed. The staff did not observe the preparation and addition of the fibrous debris for the Seabrook testing. Vendor personnel indicated that (1) two passes through a leaf shredder was also considered sufficient to generate fibrous debris with a relatively fine size distribution and (2) Seabrook has a larger quantity of fibrous debris transporting to the strainers than Fort Calhoun, not all of which is in the size range of fines. The staff recommended that the vendor consider standardizing debris preparation procedures for fine fibrous debris so that confidence will exist that the staff's comments from the Waterford 3 audit have been addressed for subsequent tests for all plants. Although the staff recognized that the fibrous debris for the Seabrook testing may contain other size ranges in addition to fines, the staff emphasized that the finest fiber in the plant-specific debris size distribution should be added to the test tank during thin-bed testing to ensure that the limiting head loss is considered.

The staff noted that relatively small head losses had been measured for many of the Seabrook tests. This outcome was somewhat unexpected, given that a sufficient quantity of fibrous debris was available for thin-bed formation. One hypothesis for the low head losses associated with the Seabrook testing was related to the large size of strainer disks, which were approximately 9 ft high by 8 ft long. Specifically, the combined effects of gravity over the 9-ft disk height and the non-uniform distribution of the suction force over the large strainer surface area could have contributed to inhibiting the formation of a uniform debris layer. However, a definitive explanation for the low measured head losses for the Seabrook testing was not identified during the staff's trip.

Conclusion

The staff concluded that the Fort Calhoun small-break LOCA head loss test case observed during the trip was conducted in a reasonable manner overall and noted that the procedure used for the observed test addressed a number of NRC staff concerns with previous GE/CDI test procedures that were identified in the staff's GSI-191 audit of Waterford 3 Steam Electric Station. In particular, the GE/CDI practice of performing repeat tests creates confidence that a conservative head loss value will result from the strainer testing program. Based on the staff's observations for the test case performed on February 18–19, 2008, no outstanding issues were designated for Fort Calhoun to resolve.

However the staff noted that significant differences were apparent in the test procedures used for the small-break LOCA test case observed by the staff and test cases for other plants and for previous test cases performed for Fort Calhoun. These other tests were outside the scope of the staff's head loss testing observations, and the staff's conclusion does not apply to these tests. Several recommended improvements to the GE/CDI test procedure were also included in the foregoing report, the implementation of which would provide increased confidence that future testing using alternate procedures would be performed in a consistent and acceptable manner.