October 27, 2008

MEMORANDUM TO: Jared S. Wermiel, Deputy Director
Division of Safety Systems

FROM: Donnie G. Harrison, Acting Chief **/RA/**
Safety Issues Resolution Branch
Division of Safety Systems

SUBJECT: STAFF OBSERVATIONS OF TESTING FOR GENERIC SAFETY ISSUE 191 AT WYLE LABORATORIES ON NOVEMBER 26/27, 2007

On November 26 and 27, 2007, Paul Klein and Leon Whitney of the Nuclear Regulatory Commission (NRC) staff traveled to the facilities of Wyle Laboratories (Wyle) in Huntsville, Alabama. The objective of the trip was to observe 30-day chemical effects head loss qualification test of an Enercon-design "top-hat" cylindrical passive strainer. The testing was intended to qualify strainer designs at the McGuire and Catawba nuclear plants. Representatives from Duke Energy and Enercon were present at Wyle Laboratories to observe and provide test coordination. NRC staff interacted with the following vendor and licensee personnel: Ralph Yeardley of Wyle, Eric Crabtree of Enercon, Ari Tuckman and Phil Roberson of Duke Energy, and Gene Martin of Duke Energy QA.

The staff on-site activities consisted of: (1) observation of the completion of a greater than 30-day strainer test, (2) disassembly of the test apparatus, and (3) post-test discussions with the licensee and their vendors. In addition, after the staff returned from the test, the NRC staff received and reviewed video showing debris preparation and debris addition at the beginning of the test. The NRC staff provided feedback to the licensee during a phone call on January 15, 2008. Staff comments on these activities are provided below.

<u>Observation of the End of the 30-Day Strainer Test</u>

The Wyle Laboratory facilities contain a test loop designed to perform strainer head loss testing. Figure 1 shows the test loop that contains a pump, piping, and a tank sloped from the inlet towards the outlet and connected to a 36-inch diameter steel pipe attached at the tank outlet. A horizontally-mounted 8-inch diameter "top-hat" test strainer was housed within the 36-inch diameter pipe. Baffle walls were welded into the pipe section in an attempt to obtain representative side clearances between the strainer and the adjacent walls. In addition, the clearance between the top hat and the bottom of the pipe simulated the approximate 3-inch clearance between the strainers and the containment floor in the plant. The single strainer test configuration was non-prototypical since the strainer arrangements in the McGuire and Catawba plants typically have two horizontally-oriented strainers mounted one above the other along the waterbox. The original test design for two strainers mounted one above the other was changed in order to address issues with chemical concentrations. During the 30-day test, water flows down the ramp towards the open end of the "top-hat" strainer, while the flows approaching the strainers in the reactor plant may have a larger side-to-side or cross-axial flow component.

The technical approach employed by Duke to evaluate chemical effects at Catawba and McGuire consisted of several key test steps. Testing was performed in borated water that was buffered with sodium tetraborate to a pH of approximately 7.8. The water temperature initially was elevated and allowed to slowly cool during the test to simulate the sump temperature profile. The plant-specific debris that was tested was a combined worst case of both McGuire and Catawba; representing fiber and particulate loads from McGuire and dissolved aluminum concentrations from Catawba. The non-chemical debris that was analyzed to reach the sump strainer was added to the tank at the beginning of the test. Additional fiber that could contribute to the water chemistry, but was not analyzed to reach the strainer, was placed in stainless steel mesh bags and suspended in the tank. The amount of aluminum was determined using a Duke algorithm developed from small-scale aluminum corrosion tests. Dissolved aluminum, in the form of aluminum nitrate, was then added to the 30-day head loss test based on the plant-specific aluminum predictions. The amount of dissolved aluminum measured by an Inductively Coupled Plasma analysis technique matched the projected aluminum concentration based on the total aluminum addition for a period of approximately 8 days. Thereafter, the measured value was a few ppm lower than the projected value. A coincident drop in the dissolved silicon measurements was noted and the licensee attributed the decreases in measured values to a precipitation process.

At the time of the staff's arrival at the Wyle facilities, the licensee was attempting to perform a final flow sweep (high flow) to check for the presence of bore holes, but this flow sweep was delayed by a pump coupling failure. The actual test duration was expanded to 34 days due to two power failures and one boiler failure during the test. The test was run to simulate all ECCS trains in operation for a scaled flow equivalent to 16,000 gpm in the plant. During the test, the debris-laden strainer module had exhibited pressure drops that ranged from approximately 1 to 4 psid at flows in the range of 110 gpm to 150 gpm.

Disassembly of the Test Apparatus

Following the final flow sweep, the pump was secured and the test loop was slowly drained. Figure 2 shows the post-test appearance looking into the 36-inch diameter pipe. A significant amount of fibrous debris had settled on the bottom of the pipe in the approximately 2.5 foot distance between the pipe inlet and the beginning of the top-hat test strainer. As seen in Figure 2, the outside surface of the top-hat strainer was essentially bare for the approximately 10 inches of screen furthest from the strainer suction end. The compressed fiber on the outer top-hat surface near the suction end was approximately one inch thick. The top-hat strainer internal surface was mostly clean except for a cylindrical "plug" of fiber approximately 8 inches long located at the suction end of the strainer. No hydrated precipitates similar to what has been observed during earlier NRC-sponsored work were visible in the fluid or on the debris bed following the test. Some fiber was observed on the downstream bypass eliminator mesh (mounted internal to the strainer cylinder) once it was removed, although the amount was not enough to raise any concern about debris bed formation on the bypass eliminator.

It could not be determined from the appearance of the fiber on the strainer module after the test whether the material was comprised of individual fibers, small pieces of fiber, or a mixture of the two. However, judging by (1) the apparent mixed nature of the material that went into the test flume, (2) the appearance of the estimated 20% to 40% of fiber lying in the strainer "near field" upstream of the strainer at the end of the test, (3) the sparse amounts of loose fibers on the downstream wire mesh "bypass eliminator" filter, and (4) the amount of clean screen area on the strainer module screen surfaces post-test, both the fiber material on the outside of strainer module and in the internal fiber "plug" were very likely comprised of a mixture of loose fibers and small pieces of fiber. Had the tested fiber distribution included more fiber "fines" (suspended and individual) fibers, a fiber bed may have formed over the entire screen surface because of the ability of loose fibers to independently and freely transport in response to the suction forces at all locations on the strainer.

Post-test Discussions

After the test apparatus was disassembled and observations and measurements of the debris material were conducted, the staff met with the Wyle, Enercon, and Duke Energy representatives.

Given the amount of fiber that settled the pipe section upstream of the strainer and the amount of bare surface on the inner and outer surfaces of the top-hat strainer, the NRC staff questioned whether the debris bed that formed during the test was representative of a debris bed that would form on the top-hat strainers in the sump following a LOCA.

Duke Energy representatives commented that the reactor plant containments for the McGuire and Catawba sump strainers have high recirculation flow rates relative to most PWR plants. The test flow rate was constant and was scaled to represent all ECCS trains operating at a 16,000 gallon per minute plant flow rate. Although the NRC staff considers the use of the high flow rate to be conservative with respect to pressure drop across a debris bed, the staff concern is related to whether the flow approaching the test strainer is prototypical of the plant. The test design seemed to direct the flow along the long axis of the top-hat strainer which may have created a sweeping effect along the surface of the strainer.

An Enercon representative theorized that the approximately 8-inch “plug” of material at the “bottom” of the inner screen surface was comprised of a succession of fiber beds which had formed on the inner screen surfaces at that end of the strainer module and then collapsed, pulling away from the inner screen surface and being drawn towards the location where the strainer module was mounted to the exit plenum. This theory is consistent with post-test pictures that showed the “plug” would easily peel apart in apparent layers along its longitudinal axis.

Post-Test Review of Debris Addition

During the visit to Wyle Laboratory, the NRC staff asked the licensee to provide photos from the debris addition at the beginning of the test. Following the visit, a Duke representative sent photos and a video to the NRC staff showing the debris preparation and the debris addition. The fiber for the test was baked and shredded before arriving at Wyle Laboratories. Then a hand-held paint mixer was applied to the material in water-filled buckets. Pictures of the five post-preparation fibrous debris buckets, as well as pictures of the material being poured from the buckets into the test flume, showed little indication that individual or suspended fibers were in the buckets, either due to ineffective shredding and mixing, or post-shredding and mixing agglomeration within the buckets. The licensee’s analysis for prototypical fibrous material generated in a McGuire/Catawba LOCA indicated that 20% fine fibers and 80% small pieces of fiber would be generated and that 100% of the fine fibers would transport while only 21.3% of the small pieces would transport. This leads to a calculated ratio of approximately 54% loose fibers versus 46% small pieces of fiber arriving at the strainers. This distribution did not seem to be consistent with the clumpy fibrous material that was poured from buckets into the tank at the start of the test.

In order to promote transport of debris to the strainer, the fibrous debris was added to the flume tank when the fluid was approximately two inches above the top of the strainer. Only the bottom portion of the sloped tank was covered with water during the debris addition and the flow during the debris addition process appeared to be turbulent. The video of the debris preparation and debris addition processes reinforced the staff's concern about whether the debris bed formed on the test strainer would be prototypical of that which may form on the strainer array following a LOCA in the plant. After reviewing the video, the NRC staff provided feedback to the licensee during a phone call on January 15, 2008.

Figure 1. Test loop for 30-day integrated chemical effects head loss test.

Figure 2. Post-test review of the top-hat strainer showing essentially bare strainer surface on the end opposite the suction side and a settled fiber pile on the pipe bottom upstream of the strainer.

Proprietary Review

On September 3, 2008, Duke Energy provided the results of their review, and their contractor's review, of this report. No proprietary information was identified by Duke Energy. Duke Energy technical comments were considered and incorporated, as appropriate.

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