December 29, 2008

MEMORANDUM TO: Michael Scott, Chief
Safety Issues Resolution Branch
Division of Safety Systems

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SUBJECT: TRIP REPORT FOR IN-VESSEL TESTS AT WESTINGHOUSE

Enclosed is the trip report prepared by the staff members who witnessed GSI-191 related in-vessel fuel blockage tests conducted at Westinghouse in Monroeville, Pennsylvania, from September 16 to 17, 2008.

Enclosure:
As noted

CONTACT: Steve Smith, NRR/DSS/SSIB
301-415-3190

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Date	12/19/08	12/19/08	12/22/08	12/24/08

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Trip Report
Flow Blockage Testing of Westinghouse 17 x 17 Fuel Assembly at
Westinghouse Research and Technology Park
September 16 and 17, 2008

Introduction

The Pressurized Water Reactor Owners Group (PWROG) is performing fuel blockage testing as a follow up to the NRC's review of topical report WCAP-16793-NP, "*Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid*". Results of the testing will be incorporated into a revision of the WCAP. NRC GSI-191 technical reviewers Paul Klein (NRR/DCI/CSGB), Ervin Geiger (NRR/DSS/SSIB), and Steve Smith (NRR/DSS/SSIB), witnessed one such fuel blockage test performed by Westinghouse on behalf of the PWROG.

Prior to observing the test, the staff reviewed test protocol documents and observed the preparation of the fiber test debris. The staff observed the initiation of a fuel assembly blockage test. This test was intended to evaluate the potential for significant pressure drop across a single, 4-ft high fuel assembly with full scale dimension (except height) of Westinghouse 17x17 fuel. The test series includes Westinghouse fuel designs and intends to bound as many PWR plants as possible based on the potential debris loading and fuel inlet nozzle types used at the various plants. Westinghouse will perform a separate test to examine the pressure drop across a Combustion Engineering fuel assembly. Additional testing will be conducted, at Continuum Dynamics Inc., to determine the potential for incurring debris related head loss with Areva fuel designs. Both the Westinghouse and Areva fuel test results will be referenced in a revision to the WCAP-16793 topical report.

Overall, the NRC staff agreed that the debris preparation and introduction methods used would produce realistic head loss test results across the mock fuel assembly. Also, the partial length mock fuel assembly allows for a more realistic debris distribution on spacer grids located throughout the fuel assembly as compared to shorter test assemblies previously observed by the staff. Previous testing conducted by a licensee was conducted on a fixture consisting of a bottom nozzle, a protective grid, and one spacer grid. For the Westinghouse testing several additional intermediate grids were included in the mock-up.

Although the staff was permitted to view the testing, and review test procedures and documents, Westinghouse did not provide test results or photographs to the staff because these were deemed preliminary and the test results are proprietary to Westinghouse.

Test Facility

Westinghouse has erected a test apparatus to perform testing of the potential for blockage of fuel at the inlet nozzles and on the spacer and mixing grids located further up in the fuel bundle. The testing is performed using postulated debris loads that could migrate to the core following a Loss-of-Coolant Accident (LOCA) as debris is pumped through the emergency core cooling systems (ECCS). The debris loading is postulated LOCA debris that has bypassed the sump strainers. The test loop developed is a relatively simple assembly consisting of a simulated core support plate, bottom nozzle, protective (P) Grid, bottom grid, two intermediate grids, a flow mixing grid, a top grid and top (outlet) nozzle. Except for the simulated core support plate, the materials used in the fuel assemblies are the materials used in the plant (without the fuel pellets and the boron). Debris surrogates, including chemical precipitates postulated to be present in the recirculating sump water, can be introduced into the test loop; and the pressure drop across various portions of the assembly can be measured as debris is captured.

The test witnessed by the staff utilized a fuel assembly inlet nozzle of the standard Westinghouse 17x17 fuel design. A Standard P-grid was used during the testing in addition to a Westinghouse standard intermediate mixing vane grid, standard top and bottom grids, and standard intermediate grids. The fuel rods and control rods were simulated by parts with the same geometry as actual fuel assembly components. The test article was supported on a Lexan plate having four flow holes the same diameter and pitch as those in Westinghouse design core support plate.

Test assembly bypass was restricted to a gap on each side of the assembly corresponding to half of the normal fuel assembly to fuel assembly gap. This gap was measured using an ultrasonic measuring device and adjusted prior to each test using set screws to position the fuel assembly. To determine the pressure drop that occurs during testing, several ports for reading pressure were installed on the test rig. These pressure ports allow differential pressure to be determined across the various components in the simulated fuel assembly.

The test was performed using Nukon fiber material that had similar characteristics of fiber that was captured downstream of the sump strainers during the emergency core cooling system (ECCS) strainer bypass testing. Samples from bypass testing performed for several plants were analyzed to determine a size distribution representative of fibers that could arrive at the core inlet. The fibrous debris was created by placing a specified amount of fiber in a blender with water and blending for a specified time. Westinghouse performed microscopic measurements on the blended fiber to determine that the prescribed process resulted in a fiber size and distribution similar to that which had been collected downstream of strainers during bypass testing. The staff reviewed the results of the analysis and found that the blending process was acceptable because it resulted in the creation of a fibrous debris size distribution that is representative of fiber that bypasses strainers under test conditions prototypical of PWRs. Additional surrogate debris was added to the test based on materials and latent debris present in plant containments.

The test that was witnessed by the staff included debris representing latent debris, coatings debris, fibrous insulation debris, and chemical debris. The debris load for this test was representative of a plant with low fiber and high particulate debris loads. A test conducted the week before the staff's visit was representative of plants with low fiber and low particulate loading. The PWROG testing plans to test separately for plants that have particulate insulation sources in containment. Future tests will include Cal-Sil and Min-K. Chemical precipitate, in the form of aluminum oxyhydroxide was prepared using the WCAP-16530-NP, *Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids in Support of GSI-191*, instructions. One-hour precipitate settlement was measured and found to be within the acceptable limit provided in WCAP-16530-NP.

Additional testing is planned for Combustion Engineering (CE) design plants. This testing will incorporate fuel assembly components prototypical of CE fuel, and a simulated core support plate that matches CE support plate characteristics.

Quantities of debris used for the test witnessed by the staff were chosen to bound some PWR potential debris loadings that do not include particulate insulation debris. Neither Westinghouse nor the PWROG have provided the staff with the basis or methodology that will be used to ensure that various licensees are bounded by the testing. The final test results have not been provided to the staff for review. The acceptance of the test results and how they are applied are activities that are beyond the scope of this trip report.

The flow rate used during the test was scaled from the flow rate that would be expected following a hot leg break. The flow rate and debris quantities were scaled to represent those expected for one fuel assembly out of a 193 fuel assembly core. The PWROG is projecting that the results of the test using the hot leg flow rate will bound the cold leg case. The staff is awaiting a test report to make a determination on the acceptability of the results and their applicability to various plants and break scenarios.

The tests were performed using the debris addition sequence of particulate followed by fiber followed by chemicals. The tests observed by the staff had the particulate debris added first, in batches, and allowed to mix with the test fluid. A total of 14 lb of particulate material was added to the test. The fibrous debris was introduced following the particulate debris in batches in order to test for a thin bed effect. After head loss stabilized, the next batch of fiber was added. Each batch was 5 grams of blended fiber which would equate to about a 1/8 inch theoretical bed. 53 grams of fiber were added to the test. After the fibrous debris was added and head loss reached a relatively stable plateau the chemical debris was added in batches.

The test procedure for the tests witnessed by the staff was as follows. First, the specified flow rate, 44.7 gpm (about 0.2 ft/sec) was established and the “clean” head loss was determined. Test fluid temperature was about 70^{o} F during the testing. The test loop contained about 250 gallons of water. Particulates were then added to the test loop followed by batches of fibers. Subsequent fiber batches were not added until the head loss stabilized. The chemical precipitates were added to the test loop in batches following a similar procedure.

Results

The results of the test performed on September 17, 2008, were not provided to the staff. However, the PWROG provided information that indicated that this test, as well as the test with a lower particulate load, both resulted in head losses less than 13 psig at hot leg flows. The head loss in the test witnessed by the staff appeared to be spread across the height of the bundle indicating that debris was captured and caused flow restrictions at the intermediate grids, as well as the bottom nozzle and P-grid. The overall pressure drop across the test assembly did not exceed the test acceptance criterion for the hot leg flow condition.

Post-test examination of the test assembly indicates that very little debris accumulated on the core support plate. There was also very little material in the bottom test chamber below the core support plate indicating that the majority of the debris transported up into the test assembly. The spacer grids trapped a considerable amount of debris. Post-test disassembly of the 4-foot tall fuel bundle revealed moderate accumulation of fiber and particulate debris at the protective grid and the spacer grids. Based on post-test visual observation, the fiber and particulate debris appeared to be evenly distributed throughout the protective grid and spacer grids. For future tests, the PWROG will have the opportunity to measure the pressure drop across each nozzle or intermediate spacer grid to determine the relative debris distribution while the test is in progress. All surfaces of the test article exhibited the gray color of the silicon carbide used as the surrogate for particulate debris.

Key Observations

1. The PWROG is making an attempt to quantify in-core debris head loss effects by testing using various debris load combinations. These tests may allow plants to determine the magnitude of head loss that could occur within the core due to post-LOCA debris deposition. Based on staff observations, the testing appears to use a valid methodology for quantifying prototypical head losses that could occur within the core at some plants. This observation is based on use of scaled flow rates, debris preparation and introduction techniques and debris quantities combined with a design-specific fuel inlet nozzle, P-grid, and intermediate grids.
2. The final test data, and the applicability of the test results to various plants and conditions still need to be reviewed and accepted by the staff.
3. The use of a longer fuel assembly illustrated that the debris collects throughout the length of the assembly on the various grids. This is probably advantageous from an overall head loss perspective because the debris will be more spread out in the core. This may result in overall lower head losses compared to a case where debris collects at a single elevation.
4. The debris preparation for the testing was observed to result in prototypical fibrous debris characteristics. This observation was based on the observation of fibrous debris preparation and a microscopic comparison of the prepared debris and debris that had been collected downstream of an ECCS strainer.
5. For the Westinghouse Standard P-Grid, it appears that a thin bed effect will not occur with relatively low fibrous loads. This is likely due to the many areas on which fiber can collect within the assembly.

Conclusions

Tests performed at Westinghouse using a Westinghouse fuel assembly inlet nozzle, a Standard P-grid and other intermediate grids, scaled flow rates, and debris representative of that for some reactor plant coolant system breaks indicate that head loss will occur across the core. The debris that collects within the fuel assembly may not totally impede the flow of coolant at the conditions tested. Additionally, it appears that the debris will deposit along the full length of the fuel assembly further reducing the head loss caused by its deposition. In this respect, the test results should be conservative since there are additional intermediate spacer grids in the full sized fuel assemblies in a core. The testing was conducted using procedures that should result in realistic or conservative head loss values. The results of the testing and the basis for applying the results to various plants were not provided to the staff for review. Therefore, no conclusions as to the acceptability of any reactor plant in-core debris loading can be made at this time based on the testing observed.