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Scoping Test on the Effects of Boron and Buffer in the Mockup PLUS7 Fuel Assembly of the APR1400

Suh Jeong-kwan*, Kwon Sun-guk, Kim Jae-won, Lee Jae-yong
KHNP Central Research Institute, 1312-70 Yuseongdae-Ro, Yuseong-Gu, Daejeon 305-343, Korea
**Corresponding author: jksuh@khnp.co.kr*

1. Introduction

To address U.S. Nuclear Regulatory Commission (NRC) Generic Safety Issue (GSI)-191 [1], we have performed a series of fuel assembly (FA) head loss tests. The goal of this test is to confirm that there is sufficient available head when the debris reaches the core inlets of the APR1400 during a loss-of-coolant accident (LOCA), and that the long-term core cooling (LTCC) is not impeded.

To move forward with the resolution of GSI-191 in-vessel effects, we have performed a scoping test on the effects of boron and buffer at ambient temperature. In test SK34-205, repeatability of the tests was confirmed at the limiting conditions. In a scoping test SK34-245, boron and Tri-Sodium Phosphate (TSP) buffer were added prior to the debris addition.

Test results of the repeatability and the boron/buffer effects are presented, and compared with the acceptance basis for the LTCC of the APR1400.

2. Description of the Tests

2.1 Test Facility

A schematic of the test loop used for SK34-205 and SK34-245 is provided in Figure 1. The test loop is composed of four main parts; mixing tank system, circulation system, test pool, and control and monitoring system. Detailed descriptions of the test facility are given in Reference 2.

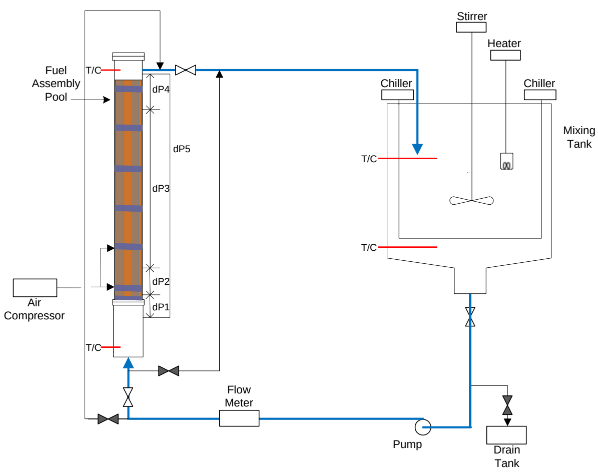

Fig. 1. Schematic of the test loop for the APR1400

2.2 Test Procedure

The PWR Owners Group (PWROG) developed a common test protocol to ensure that testing for all PWROG members was consistent among all PWROG fuel test programs. The test procedures, debris details, and pressure drop acceptance basis for this testing were developed based on this protocol and WCAP-16793-NP [3]. Detailed descriptions of the test procedure are given in Reference 2.

2.3 Test Conditions

The debris types and amounts used in the tests are found in Table 1. The stable flow rate (77.6 lpm) and temperature (22 °C) conditions are established. All tests use a sequential debris addition procedure. The pressure drops across five locations are monitored. The tests are terminated when all the debris is added and the pressure drop is stable or unacceptably high pressure drop is reached.

Table 1: Test matrix for in-vessel downstream effect

Test No.	Particulate (g)	Fiber (g)	AlOOH (g)	Notes
SK34-205	100	100	50	Repeatability
SK34-206	100	100	100	
SK34-207	100	100	200	
SK34-208	100	100	300	
SK34-245	100	100	50	Included boron and TSP buffer
SK34-246	100	100	100	
SK34-247	100	100	200	
SK34-248	100	100	300	

2.4 Acceptance Basis for the Repeatability Test

The acceptance basis for the repeatability test are defined as follows;

- The original and repeatability test results should be less than the acceptance basis for the pressure drop.
- The difference between the original and the repeatability test result should be less than 25 % [3].

3. Test Results

Table 2 contains a summary of the pressure drop results obtained for all the tests. The results are discussed in detail in the following sections.

Table 2: Summary of test results

Test No.	Max. FA Head Loss (kPa)	
	Before Chem.	After Chem.
SK34-205	9.975	18.419
SK34-206	9.975	17.856
SK34-207	9.975	18.981
SK34-208	9.975	19.456
SK34-245	7.900	8.706
SK34-246	7.900	9.206
SK34-247	7.900	9.344
SK34-248	7.900	9.313

3.1 Repeatability Test (SK34-205~208)

The goal of tests SK34-205~208 is to evaluate the repeatability of the tests. These tests are a repeat of SK34-61~64 [2]. Post-LOCA conditions with maximum flow after a hot leg break are simulated.

The maximum pressure drop recorded for these tests is 19.4 kPa. The repeatability compared with the results of SK34-61~64 (20.78 kPa) is confirmed within 7% difference. The results for SK34-205~208 are plotted in Figure 2.

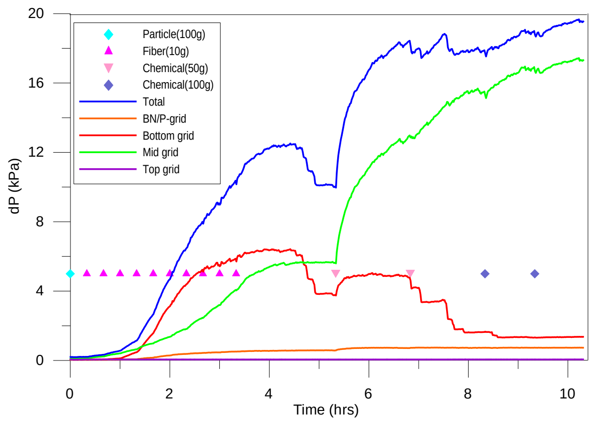

Fig. 2. Repeatability test results (SK34-205~208)

3.2 Boron and Buffer Effect Test (SK34-245~248)

The purpose of this scoping test is to establish the pressure drop characteristics of a mockup FA when debris, boric acid, and TSP are contained in the simulated coolant.

The maximum pressure drop recorded for this test is 9.34 kPa which is less than that without boron and buffer (SK34-205~208). The results for SK34-245~248 are plotted in Figure 3.

Consistent with reference FA tests (SK34-205~208), the SiO_2 particulate addition has little to no effect on the pressure drop.

Overall, the fiber additions cause a relatively steady increase in the pressure drop across the entire FA. In addition to the pressure drop across the entire FA, dP readings are collected at the Bottom Nozzle (BN)/p-grid location. SK34-245~248 started accumulating debris at this location after 10 grams of fiber had been added to the test loop.

AlOOH, which is a chemical surrogate, is added to the test loop after the completion of the fiber additions and the pressure stabilization. Upon the first chemical addition of 50 g, the overall dP increases from 7.9 kPa to 8.7 kPa. The following addition of AlOOH does not significantly cause an increase in the pressure drop.

SK34-245~248 only formed four debris beds. The debris beds formed at the BN/p-grid, bottom grid, lower mid-grid 1 and lower mid-grid 2. The beds remained at these locations and continued to develop as fiber was added. The addition of chemicals did not change the number of beds.

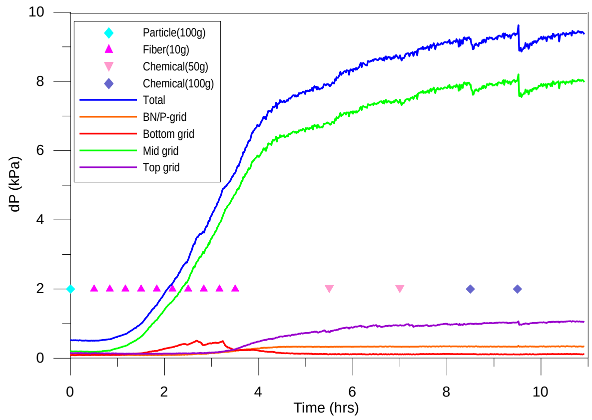

Fig. 3. Boron and buffer test results (SK34-245~248)

4. Conclusions

To address GSI-191 of the APR1400, we have performed a series of FA tests using a mockup PLUS7. The test results of repeatability performed at limiting conditions meet the acceptance basis compared with the reference results (SK34-61~64) within 7% difference. Boron and buffer in the fluid lowered pressure drop across the entire FA compared with the condition without them.

The test results of boron and buffer effects meet the acceptance head loss (91.8 kPa) of the APR1400 with a sufficient margin.

REFERENCES

[1] Generic Safety Issue 191, "Potential of PWR Sump Blockage Post-LOCA," 1998.
[2] J.K. Suh et al., "In-vessel Downstream Effect Tests for the APR1400," Proceedings of ICAPP 2013, Jeju Island, Korea, April 14-18, 2013.
[3] WCAP-16793-NP, Rev. 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," 2011.