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Evaluation for the Impact of Debris Settling on the In-vessel Downstream Effect Tests of the APR1400 Design

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1. Introduction

The in-vessel downstream effect tests for the APR1400 design were performed to demonstrate that sufficient available head is maintained with debris and chemical products which are postulated to be transported to the reactor vessel following a loss-of-coolant accident (LOCA) [1]. Four tests were run to evaluate hot-leg break conditions with a four safety injection (SI) flow rate varying particle to fiber (P/F) ratios of 0.5, 1, 2, and 10. Seven tests were run to evaluate cold-leg (CL) break conditions with a core boil-off rate at 700 seconds after a LOCA with varying P/F ratios of 1, 10, 20, 30, 40, 50, and 60.

The phenomenon of debris settling was observed at the inlet of test column when simulating cold-leg beak, as shown in Fig. 1. In this paper, the applicability of the test results was evaluated by providing pressure drops through debris bed in which condition debris settling did not occur under the same P/F mass ratio.

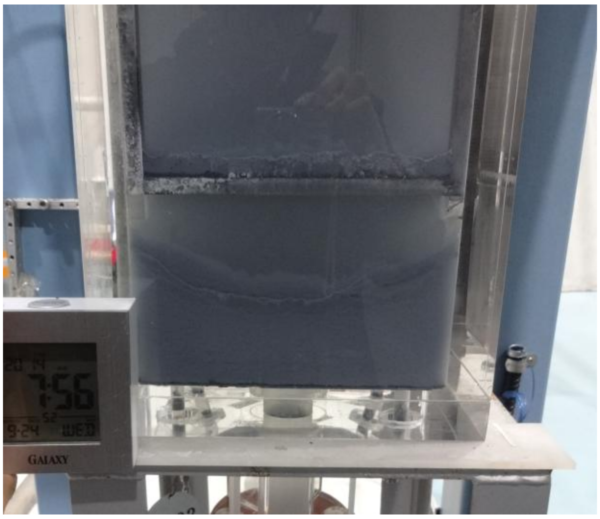

Fig. 1. Debris settling under the CL break tests

2. Evaluation Method and Results

2.1 Conservatism in the Test Design

Two conservative parameters were selected to cope with debris settling in the cold-leg break tests, as described in Table 1. The flow rate during the cold-leg break tests was set to an increased value of 144% compared to the boil-off rate at 700 seconds after a LOCA. The increased flow rate induces increased pressure drops, as shown in Fig. 2, and gives conservative test results.

The quantity of fibrous debris used in the tests was set to an increased value of 391% compared to the plant data. This implies that 74.4% of debris settling is allowed to simulate cold-leg break conditions.

In addition, debris settling at the structures and debris filtering at the sump strainers expected in the plant were not credited in the tests for conservatism.

Table I: Conservatism in the Tests Considering Debris Settling

Parameter	APR1400 condition	Test condition	Remark
Flow rate during the CL break test	11.5 lpm	16.6 lpm	Increased (144%)
Quantity of fibrous debris	3.83 g	15.0 g	Increased quantity (391%)

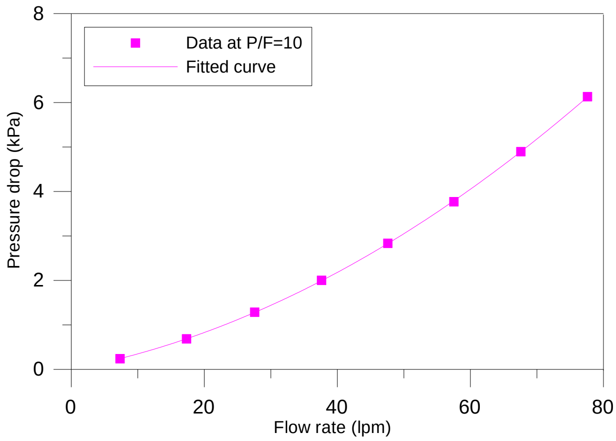

Fig. 2. Pressure drop dependence on the flow rate

2.2 Bounding Value of the Pressure Drop

The maximum pressure drop under the cold-leg break tests occurred when the P/F ratio was 50, as shown in Fig. 3. The maximum pressure drop at the P/F ratio of 50 under the hot-leg break test is expected to be less than that at a P/F ratio of 10, as indicated in Fig. 4. Thus, the maximum pressure drop at a P/F ratio of 50 is less than the "Fitted upper bound" in Fig. 5.

The fibrous debris used in the test is NUKON® with an as-fabricated specific gravity of 0.038, and the particulate debris is SiC with a material specific gravity of 3.2. This indicates that the settling probability of particulate debris is higher than that of fibrous debris, and that the maximum pressure drop occurred at P/F mass ratios which ranged from 1 to 50 in the cold-leg break tests. In Fig. 5, the maximum pressure drops at P/F ratios of 1 and 10 are below the "Fitted upper bound."

Thus, the maximum pressure drops at P/F ratios in a range of 1 to 50 are below the maximum value (7.2 kPa) of the "Fitted upper bound" in Fig. 5 despite the fact that debris settling does not occur, because it does not occur at a two SI flow rate (38.8 lpm) and a four SI flow rate (77.6 lpm).

The maximum pressure drop under the cold-leg break tests without debris settling is below 7.2 kPa, and it meets the available head limit (15.1 kPa) with a margin of approximately 52.3%.

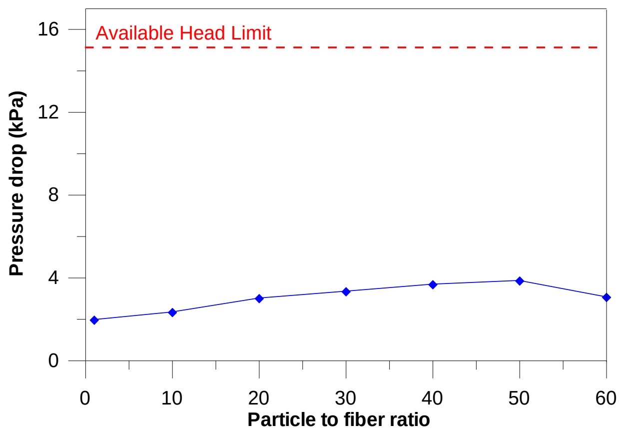

Fig. 3. Pressure drops vs. particle to fiber ratio under a cold-leg break condition

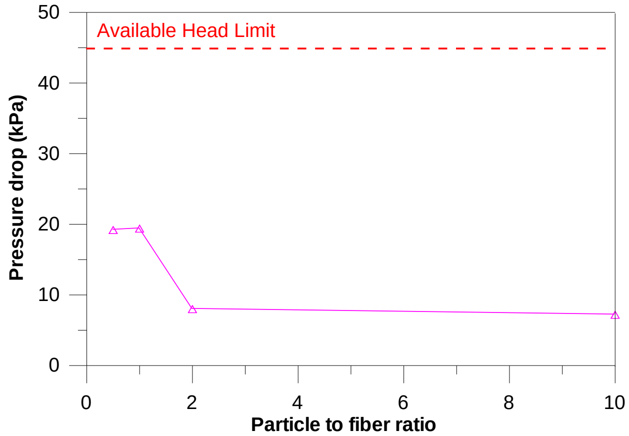

Fig. 4. Pressure drops vs. particle to fiber ratio under a hot-leg break condition

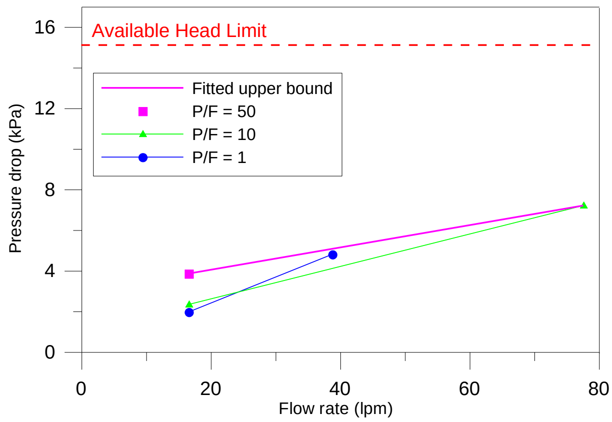

Fig. 5. Pressure drops vs. flow rates at different P/F ratios

3. Conclusions

The impact of debris settling on the validity of testing that has been conducted to address in-vessel downstream effects of the APR1400 was evaluated in this study. The test results that have been conducted with some debris settling are valid with a margin of approximately 52.3% under the cold-leg break condition.

REFERENCES

[1] APR1400-K-A-NR-14001-P Rev.0, "In-vessel Downstream Effect Tests for the APR1400," December 2014.

[2] WCAP-16793-NP Rev.2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," October 2011.

[3] USNRC, "Final Safety Evaluation by the Office of Nuclear Reactor Regulation: Topical Report WCAP-16793-NP, Revision 2," April 2013.