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Core Inlet Blockage Test Facility for the APR1400

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1. Introduction

The scope of Generic Safety Issue 191 (GSI-191) addresses a variety of concerns associated with the operation of the emergency core cooling system (ECCS) and the containment spray system (CSS) in the recirculation mode [3]. These concerns include debris generation associated with a postulated high energy piping break, debris transport to the containment sump when the ECCS is operated in the recirculation mode, and the effects of debris that might pass through the sump strainer screens on downstream components and fuel regions.

The APR1400 plant is a new type plant, and sump strainer is installed to prevent the debris transport to a downstream region. To resolve the downstream effect concern, KHNP conducts validation tests of in-vessel downstream effects to confirm meeting the criteria of form blockages at spacer grids of fuel assembly (FA) or adhere to the fuel cladding by debris. This paper describes the core inlet blockage (CIB) tests for the APR1400 FA.

2. Test Facility

KHNP designed a test loop to measure the pressure drop across the core fuel region of the APR1400 with a PLUS7 FA. The test loop is shown in Figure 1.

2.1 Mixing Tank System

The mixing tank system includes a transparent acryl tank with cylindrical shape and a debris stirring tool. The mixing tank is where debris can be added during the test. The mixing tank is manufactured as 1.5 m diameter and 1.5 m height. The debris stirring tool is installed in downward vertically at the top of the mixing tank. The mixing tank has one water suction in downward vertical directions. A chiller piping and heater are installed in mixing tank to control water temperature condition. This heater is connected with temperature control system, and the water temperature can be controlled from an environmental temperature of approximately 20 ^{o}C to a high temperature of approximately 60 ^{o}C. The water temperature is measured continuously in the tank by a submerged thermocouple.

2.2 Recirculation System

The recirculation system pumps the water from the tank, through the recirculation piping and test column, and back into the tank. A 1 kW pump draws the water out of the bottom of the mixing tank. The flow rate is controlled by a control system with computer. A magnetic flow meter measures the flow rate and provides feedback to the control system to maintain constant flow rate. A specific flow rate can be chosen and the flow control automatically regulates the flow rate to maintain that value.

2.3 Test Column

The The FA test column is made of with transparent acryl of 30 mm thickness to be visible inside the pool during the test. The test pool contains a PLUS7 mockup of 2.5 m height without fuel. The FA mockup includes a lower plenum bottom nozzle, debris capturing fuel filter, 16 x 16 fuel rods, four (4) spacer grids and top nozzle. The water flow enters from through a 40 mm nozzle at the bottom of the test column and flows upward and exits through 40 mm outlet at the top of the pool. The bottom region is made in cone shape to avoid the settling and loss of debris during the test. The test FA is located on the simulated core support plate of 30 mm thick with 70 mm flow holes.

The water with debris is injected through the bottom nozzle and flow up through the simulated core support plate. As debris catches on the FA, the differential pressure is measured constantly across the combination of bottom nozzle and bottom grid as well as across the entire FA. The height of the bottom portion and top portion of the FA pool are 500 mm and 300 mm respectively.

2.4 Control and Monitoring System

The computer control system continuously controls the following parameters:

- Water flow rate
- Water temperature

The computer monitoring system continuously records the following data:

- Temperature of the water in the mixing tank
- Temperature of the water in the test column
- Flow rate
- Differential pressure from all dP gauges

The data can be recorded at a time interval chosen by the operator. The computer is also used to check the slope of the dP or flow versus time graphs in order to determine if the curves have reached a point close enough to equilibrium

Fig. 1. CIB test loop for the APR1400

3. Test Conditions

3.1 Test Parameters

This test should reflect the recirculation flow, temperature and debris conditions under the recirculation modes after a LOCA. After a LOCA, the recirculation flow rate is 18,699 lpm, and the debris type and amount in the reactor building are presented in the APR1400 FSAR. The number of APR1400 fuel assembly is 241.

For a hot leg (HL) break, the entire ECC water must pass through the core to exit the break. The core level is at least equal to the HL nozzle elevation, and the core flow rate is equal to the ECC flow rate. Therefore, the flow rate to be tested is calculated to divide 18,699 lpm by 241 and its value is 77.6 lpm. The HL break condition at the maximum flow rate represents the most conservative test conditions and should be used for testing designed to define debris limits.

3.2 Test Matrix

The test matrix is shown in Table 1. Since the debris condition of hot-leg break and cold-leg break accident conditions are different to each other, two tests are intended.

Table 1: Test Matrix for the APR1400 CIB Test

Parameter	Test valves
Flow Rate(lpm)	77.6, 11.4
Particulate debris (g)	50, 100, 500, 6,300
Fiber debris (g)	50, 100
AlOOH (g)	50, 100, 200, 300

4. Test Procedure

The 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, pressure drop acceptance criteria for testing, and test matrix were developed based on PWROG test protocol and WCAP-16793-NP [5].

The test procedure is outlined in the following steps.

1) The mixing pool is filled with water.
2) Debris quantities are measured and verified.
3) The pump is started, and the flow is set to the desired flow rate.
4) The heater is started, and the temperature is set to the desired temperature.
5) Stabilize at a constant temperature ± 1 ^{o}C.
6) Start data acquisition system.
7) Record the clean pressure drop.
8) Particulate debris is added to system, and the pressure drop is recorded.
9) Fiber is added in loop and at least two turnover times are allowed to pass between additions until either a previously defined maximum mass of fiber or the pressure drop exceeds the defined safety limits of the facility. Pressure drop is recorded.
10) Chemical precipitates are added and pressure drop is recorded.
11) Pressure drop is allowed to reach a predefined steady state for test termination. The final pressure drop readings are recorded, and the test is terminated.

5. Conclusions

The CIB tests facility for the APR1400 FA has been developed by KHNP. The test loop is composed of four main parts as mixing tank system, recirculation system, test column, and control and monitoring system. The test parameters such as flow rate, particulate debris, fiber debris, and chemical product were chosen according to LOCA scenarios. The number of APR1400 FA is used for scaling factor. The test procedure follows a common test protocol developed by PWROG. The CIB tests for the APR1400 FA will be performed following the test matrix.

REFERENCES

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